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<p>This appendix to the DoD Weapon Systems Software Management Study conducted by APL contains information on Shipborne Systems presented in more detail than is given in the main report. The specific systems discussed are the DLG-28, DDG-9, and DLGN-38 Combat Systems, the Aircraft Carrier (CV) Tactical Data System, and the AEGIS Weapon System. Each section is divided into the following parts: General System Description; Computer System Architecture; Computer Program Architecture; Software Definition, Design, and Implementation; Software Validation and Integration; Software Acquisition Management Organization and Methods; Operational Software Maintenance; and Highlights.</p>			

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Software management
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Computer System Management

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Provisions for growth
Requirements analysis and validation
System integration and test capability
Systems engineering
Systems engineering agent
Technical staffing of program manager organization

Computers

AN/UYK-7
AN/UYK-20
CP-642/USQ-20
CP-642B/USQ-20
CP-789/UYK
CP-848/UYK
Mk 157

Weapon Systems

AEGIS
CV
DDG-9
DLG-28
DLGN-38

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DOD WEAPON SYSTEMS SOFTWARE MANAGEMENT STUDY APPENDIX B, SHIPBORNE SYSTEMS

THE JOHNS HOPKINS UNIVERSITY ■ APPLIED PHYSICS LABORATORY

Johns Hopkins Road, Laurel, Maryland 20810

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ABSTRACT

This appendix to the DoD Weapon Systems Software Management Study conducted by APL contains information on Shipborne Systems presented in more detail than is given in the main report. The specific systems discussed are the DLG-28, DDG-9, and DLGN-38 Combat Systems, the Aircraft Carrier (CV) Tactical Data System, and the AEGIS Weapon System. Each section is divided into the following parts: General System Description; Computer System Architecture; Computer Program Architecture; Software Definition, Design, and Implementation; Software Validation and Integration; Software Acquisition Management Organization and Methods; Operational Software Maintenance; and Highlights.

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1. INTRODUCTION

1.1 OBJECTIVES AND APPROACH

The Weapon System phase of the APL DoD Weapon Systems Software Management Study was concerned with specific applications of software design and management to major Weapon Systems. The systems were selected to represent a variety of platforms and major missions and to illustrate all phases of the Weapon System life cycle.

The survey of individual Weapon Systems, as a major input to the overall APL study, had the following objectives:

1. To serve as a basis for understanding how and what Weapon System software is being or has been developed, produced, deployed, and maintained in the user environment;
2. To serve as a basis for distinguishing among the large range of uses of software in Weapon Systems; differences in function, size, and complexity; and the way these differences affect software problems and potential solutions;
3. To provide insight into the organizational relationships between the Government Program Managers, system contractors, software contractors, and Government test, maintenance, and training facilities;
4. To identify design and management techniques that have proved successful and that warrant more general application; and
5. To obtain opinions from key personnel concerning ways in which the Office of the Secretary of Defense or the Services can contribute to the improvement of software cost and performance.

The survey of Weapon System software was carried out through the auspices of the respective Program Managers. System and software contractors were visited, where possible, to obtain first-hand information on system characteristics and development methods.

The selected Shipborne Weapon Systems are listed in Table 1-1. Two other appendices in this study discuss Airborne Systems and Undersea and Landbased Systems. These three appendices present more detailed information than was given in Section 4 of the main report.

TABLE 1-1
WEAPON SYSTEMS INVESTIGATED

Weapon System Programs	Systems	Status
DLG-28	Combat System Tactical Data System Terrier Weapon System	Deployed
DDG-9	Combat System Tactical Data System Tartar Weapon System	Deployed
DLGN-38	Combat System Command and Control System Sensor Interface Data System Tartar Weapon System Gun Fire Control System Underwater Fire Control System	Production
CV	Tactical Data System Aircraft Landing System Missile Fire Control System	Deployed
AEGIS	AEGIS Weapon System	Development

The individual discussions vary in detail because of the differing stages of development of the different systems. The following kinds of information were sought:

1. General System Description: A sufficient description to provide understanding of the overall system mission and requirements and the operating environment of the embedded computer system;
2. Computer System Architecture: The selection of computing equipments and their operating relationships, including the functions allocated to each computational unit;
3. Computer Program Architecture: The structure used in computer program design throughout the system, including allocation of functions to elements of the computer programs;

4. Software Definition, Design, and Implementation Methods: Techniques used in software system design management and control, especially those which have had apparent success;
5. Software Validation and Integration Methods: Management techniques, testing tools and techniques, and facilities used in software quality assurance;
6. Software Acquisition Management Organization and Methods: Methods used by the Government, system contractor, and software contractor to manage the process of software design and validation; and
7. Operational Software Maintenance: Approach used or plans for transfer of developed software to Government control for lifetime support and maintenance.

Each paragraph in the Highlights section for each Weapon System is followed by one or more designations in parentheses (e.g., (SE1)). Such a designation(s) indicates the APL recommendation(s) from the main report that correlate most closely with the particular highlight.

1.2 SHIPBORNE SYSTEMS

The current and projected Fleet deployment of ships either carrying digital equipment or planned for digital systems includes 12 carriers, 29 destroyers of the DDG class, 7 cruisers of the nuclear-powered DLGN-36 and DLGN-38 classes (to be redesignated), 30 cruisers of the DLG class (to be redesignated), and a unique cruiser (CGN-9).

Four of these ship classes, together with the Navy's newest air defense combat system (AEGIS), were selected for study since they represent successive phases in the evolution of digital Weapon Systems in the U.S. Navy.

DLG-28 (USS Wainwright) exemplifies the currently deployed Naval Tactical Data System with the recent addition of digital fire control capability.

DDG-9 (USS Towers) represents recent updating of selected Guided Missile Destroyers with a digital Tactical Data System.

DLGN-38 (USS Virginia) is one of a new class of Guided Missile nuclear frigates now under development and using an extensive centralized complex of modular AN/UYK-7 computers.

CVAN-68 (USS Nimitz) is the most recently commissioned aircraft carrier with digital Tactical Data and Aircraft Control Systems. Digital missile fire control systems are also installed on certain ships of the CV class.

A Strike Cruiser was selected to represent a possible future ship outfitted with the AEGIS Weapon System.

Figure 1-1 represents the relative complexity of digital systems in the selected ships. The figure shows major computers, peripheral memory, and operator consoles. These are segmented by the basic functions of a combat system: target detection, combat direction, weapon control, and operability testing. The memory available to system computers is represented by the vertical scale; processors are represented by symbols. The number of operator consoles involved in these functions is also represented by symbolic blocks. The figure shows the growing trend toward automation, particularly in the functions of detection and systems test. This trend is accompanied by a reduction in the number of operators required for manual tasks of target position plotting.

Table 1-2 summarizes the types of digital computers employed in these shipboard systems. There has been a strong tendency to standardize the computer equipment used in shipboard combat systems. The USQ-20, CP-789, and CP-848 computers have been used in a variety of ship applications. The AN/UYK-7 and AN/UYK-20 computers implement more recent technology and are designated by the Navy as "standards" for current and future shipboard tactical digital applications.

DLG-28 (USS Wainwright), deployed in 1966, was the first operational ship to carry a complete Naval Tactical Data System (NTDS). The growth of digital capability in the Fleet from the initial digital systems in support of command and control to the present inclusion of digital fire control has been an evolutionary process, resulting from early pioneering in this area by the Naval Ship Engineering Center (NAVSEC).

Responsibility for acquisition and maintenance of software and systems has been divided among several participating organizations with equipment responsibility typically at NAVSEC and software responsibility at Fleet Combat Direction System Support Activity (FCDSSA), Dam Neck (DN) or San Diego (SD). A significant part of the testing of these systems is conducted at the Navy's Mare Island Facility and aboard Fleet units.

Both digital hardware and software have advanced through many stages of development. The lessons learned within the framework of the NTDS development have led to several generations of standard computers,

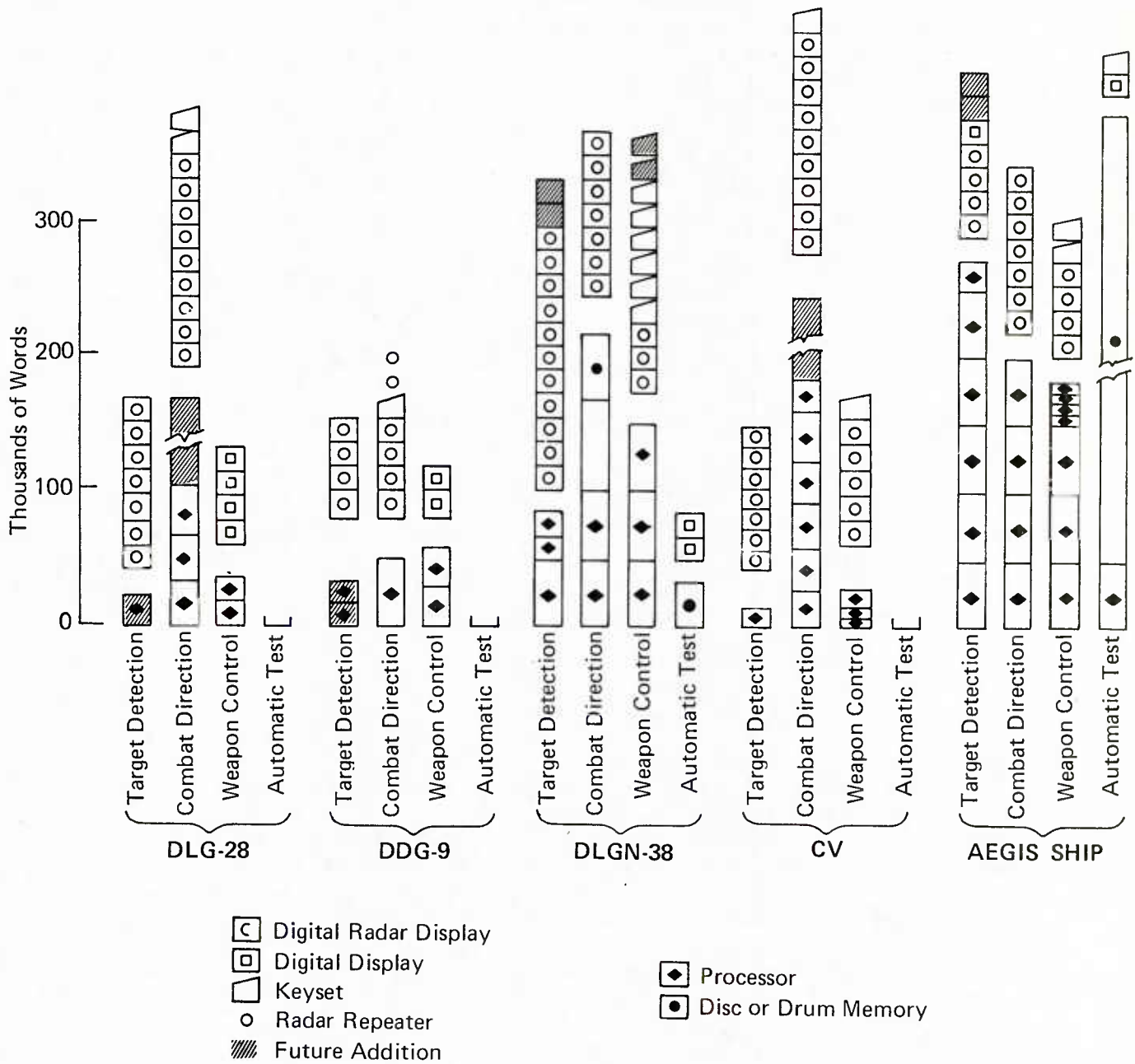


Fig. 1-1 Comparison of Shipborne Systems

TABLE 1-2
SHIPBORNE COMPUTERS

Computer Designation	Word Length (bits)	Cycle Time (μ s)	System	No. of CPU's
CP-642/USQ-20	30	8	DLG-28	3
CP-642B/USQ-20	30	4	CVAN-68	5
CP-789/UYK	18	4	DLG-28	2
			CVAN-68	2
CP-848/UYK	18	2	DLG-28	2
			DDG-9	2
			CVAN-68	2
Mk 157	16	1	CVAN-68	1 (option)
AN/UYK-7	32	1.5	DDG-9	1
			DLGN-38	6
			AEGIS Ship	14
AN/UYK-20	16	0.75	DDG-9	2 (future)
			AEGIS Ship	8

of which the AN/UYK-7 and AN/UYK-20 represent the latest. In a similar manner, standard displays have also evolved, with the AN/UYA-4 Display Group being the latest example. Methods of programming have advanced from the dedicated processing of the early years to substantial amounts of shared-memory processing and some use of multiprocessing. Recent hardware developments have shown a growing interest in the use of limited special-purpose processing (e.g., microprocessors). Lessons learned in these programs have indicated a growing need for:

1. Strong program management, from inception to development maintenance,
2. Detailed documentation requirements,
3. Standard high-level language development (CS-1, CMS-2),
4. Standard equipments, general and special purpose,

5. Functional system segments and common modules,
6. Firmly controlled interface specifications, and
7. Rigorous control of testing and changes.

The trend in shipboard digital instrumentation has progressed to include digital fire control in a significant number of our surface combatants. The development of these fire control systems has been independent but has made extensive use of NTDS equipments and technology.

Implementation of Automatic Detection and Tracking (ADT) of sensor information has received substantially less attention than is desirable. A requirement for identification friend or foe (IFF) beacon video processing was imposed on the Fleet during deployment in SEASIA to cope with the heavy track load and maintain appropriate classification of targets. A number of other systems are currently undergoing development, selected elements of which will be installed in future ship improvement programs. Among these are the AN/SPS-48C radar and the AN/SYS-1 Integrated Automatic Detection and Tracking (IADT) system.

Major support systems aboard ships are also undergoing rapid change with automatic digital processing and control providing the prime forcing factor. Among these are systems for navigation, communication, and specialized functions such as aircraft landing control systems. A major growth in force and Fleet level coordination of command, control, and communications (C³) functions is expected in future years.

Computer control of operational readiness test and fault isolation is expected to continue to advance. Replacement of the analog fire control computer with a digital computer has resulted in a major improvement in reliability. The Operational Readiness Test System (ORTS) of AEGIS represents a major improvement in this area. Increasing development of computer-controlled on-line testing is expected in future improvement programs.

Information was gathered on shipboard Weapon Systems through visits to Program Managers and contractors, as well as through reference to APL/JHU personnel who have been directly involved with associated programs. The principal agencies visited are listed in Table 1-3.

TABLE 1-3
WEAPON SYSTEM PROGRAM VISITS

Weapon System Program	Agency Visited	Responsibility	Date (1975)
DLG-28	NAVSEA 6541 FCDSSA(DN)	Program Manager (Terrier) Development and Maintenance Agent	3/4 2/11-12, 3/12-13
DDG-9	NAVSEA 6542 FCDSSA(DN)	Program Manager Development and Maintenance Agent	3/4 3/13
	Raytheon Co.	Software Contractor	3/17
DLGN-38	NAVSEA, PMS 378 NAVSEC 6172 FCDSSA(DN) Raytheon Co.	Program Manager Development Agent Maintenance Agent Software Contractor	3/10 3/4 3/12-13 3/17
CV	FCDSSA(SD)	Development and Maintenance Agent	2/25-26
AEGIS	NAVSEA, PMS 403 RCA Corp.	Program Manager System Contractor	2/24 2/12-14

2. DLG-28 COMBAT SYSTEM

2.1 GENERAL SYSTEM DESCRIPTION

DLG-28 (USS Wainwright) is one of 30 DLG's armed with the Terrier or Standard Missile (SM-1) missile Weapon System. DLG's 6 through 15 were recently modernized to the same functional capability as DLG's 28 through 35, as were DLG's 16 through 25. The latter have missile batteries fore and aft as contrasted to DLG's 6 through 15 and DLG's 26 through 35 which have single batteries. These ships all have Naval Tactical Data Systems (NTDS) and Terrier Digital Fire Control Systems (DFCS).

The mission of the DLG is to operate independently or with strike forces, antisubmarine forces, or hunter/killer groups to provide area antiair warfare (AAW) defense for convoys or amphibious assault forces, and to coordinate engagement of submarine, air, and surface threats.

The major subsystems of the DLG-28 combat system are the sensor system, the combat direction/weapon direction system, and the missile, gun, electronic warfare, and antisubmarine warfare Weapon Systems. These subsystems are integrated into the total combat system to support tactical operational requirements for target detection, tracking, identification, evaluation, and assignment to weapons for controlled engagement.

2.1.1 Sensor System

The primary capability for detection, tracking, and identification of air and surface targets is provided by the search radar system and its associated identification friend or foe (IFF) equipments. The DLG-28 is equipped with a surface search radar (AN/SPS-10), a three-coordinate long-range air-search radar (AN/SPS-48), and a two-coordinate long-range air-search radar (AN/SPS-43). The IFF capability for the DLG-28 is provided by the Automatic Identification Mk XII System (AIMS).

Video processing equipment designated as the Beacon Video Processor (BVP) operates on IFF data to provide an automatic identification capability for friendly aircraft. The BVP system includes a general-purpose digital computer (CP-789/UYK) and associated software.

The primary capability for subsurface target detection and tracking on the DLG-28 is provided by a sonar detection-ranging set (AN/SQS-26BX).

The electronic support measures (ESM) functions of the DLG-28 are provided by an electronic warfare system (AN/SLQ-26) and an electronic countermeasures receiver set (AN/WLR-1).

2.1.2 Combat Direction/Weapon Direction System

Combat direction functions on the DLG-28 are provided by the NTDS. The primary elements of NTDS are a data processing system, a display system, data communications equipments, and miscellaneous data conversion equipments. Integrated with NTDS and sharing common equipments is the Weapon Direction System (WDS) Mk 11.

The data processing system includes three general-purpose digital computers, associated software, and various peripheral devices. The communication system includes equipments that provide the capability for the DLG-28 to participate in data exchange over data Links 4A (digital control data to aircraft), 11 (computer-to-computer data exchange with remote units), and 14 (tactical data from Tactical Data System (TDS) to non-TDS units).

2.1.3 Weapon Systems

The primary Weapon System aboard the DLG-28 is the Terrier guided missile system. There are two missile fire control systems (Mk 76 Mod 6), and each is supported by a general-purpose digital computer (Mk 152) and associated software. Missiles are launched from a guided missile launching system (Mk 10 Mod 7), which is shared with the antisubmarine warfare (ASW) system.

The DLG-28 gun Weapon System consists of a gun fire control system (Mk 68 Mod 8), a 5"/54 gun mount, and two 3"/50 gun mounts.

ASW functions are supported by an underwater battery fire control system (Mk 114 Mod 12), ASROC missiles launched from the Terrier launcher, and two torpedo tubes.

Electronic warfare functions are supported by two electronic countermeasures (ECM) sets (AN/SLQ-22).

2.1.4 Acquisition History

The DLG-28 was the first Navy ship with a fully automated NTDS. The addition of digital fire control has further extended the digital capability. The future incorporation of an AN/SPS-48C radar with Automatic Detection and Tracking (ADT) and an SM-2 missile capability will make this a highly capable ship.

NTDS Operational Program (Combat Direction System): The first operational NTDS for DLG's were deployed in 1962, and Service Test Programs, Model 0, were provided to several NTDS ships. These were limited capability programs designed primarily for support of antiair warfare requirements. During the 13 years following this initial capability, NTDS programs have undergone extensive modifications both to structure and to operational capabilities. The present programs are designated as Model III programs. The most capable of these is the Phase 3 version, which supports Antiship Missile Defense (ASMD) improvements and the DFCS on DLG-28 class ships. Beginning in July 1976, Model IV NTDS operational programs will replace Model III programs in DLG-28 class ships, as well as other units equipped with Link 11 communication equipments.

The 13-year period of development for DLG NTDS operational programs was accompanied by a learning process in the control and management of software development for complex real-time tactical data processing systems. Many of the procedures in present use resulted from lessons learned during early NTDS program development.

After the initial version of the NTDS DLG operational program was successfully deployed, it was turned over to the Fleet Combat Direction System Support Activity (FCDSSA) at Dam Neck (DN), Virginia, for maintenance. Further modifications are then supervised by FCDSSA personnel. Since the initial program was turned over to FCDSSA, subsequent development has been almost entirely under the auspices of this activity. There has been no recent program acquisition as such, but there is a continuing process of modification by an on-site subcontractor under a level-of-effort contract. This is also true for in-process Model IV developments for DLG-class ships. During the process of program revision, FCDSSA also acts as integration agent and validation agent for the Navy.

DFCS Operational Program: Development of the DFCS Operational Program began in 1969. At that time the program was designated as the Terrier Adaptive Fire Control System (AFCS) computer program. APL/JHU designed the Advanced Development Model (ADM) version of this program. During early design phases, the program was redesignated as the Digital Fire Control System computer program. Vitro/Automation Industries was assigned production responsibility. The first production DFCS was evaluated in 1972 aboard the DLG-26. A follow-on version of the DFCS was designated as the Universal DFCS computer program. The Universal Program was designed to operate with Mk 76 Mods 6, 7, and 8 DFCS's. The DLG-28 received DFCS modification in 1974.

2.1.5 System Diagram

A system block diagram of the DLG-28 combat system is shown in Fig. 2-1. Functional changes being provided by the introduction of

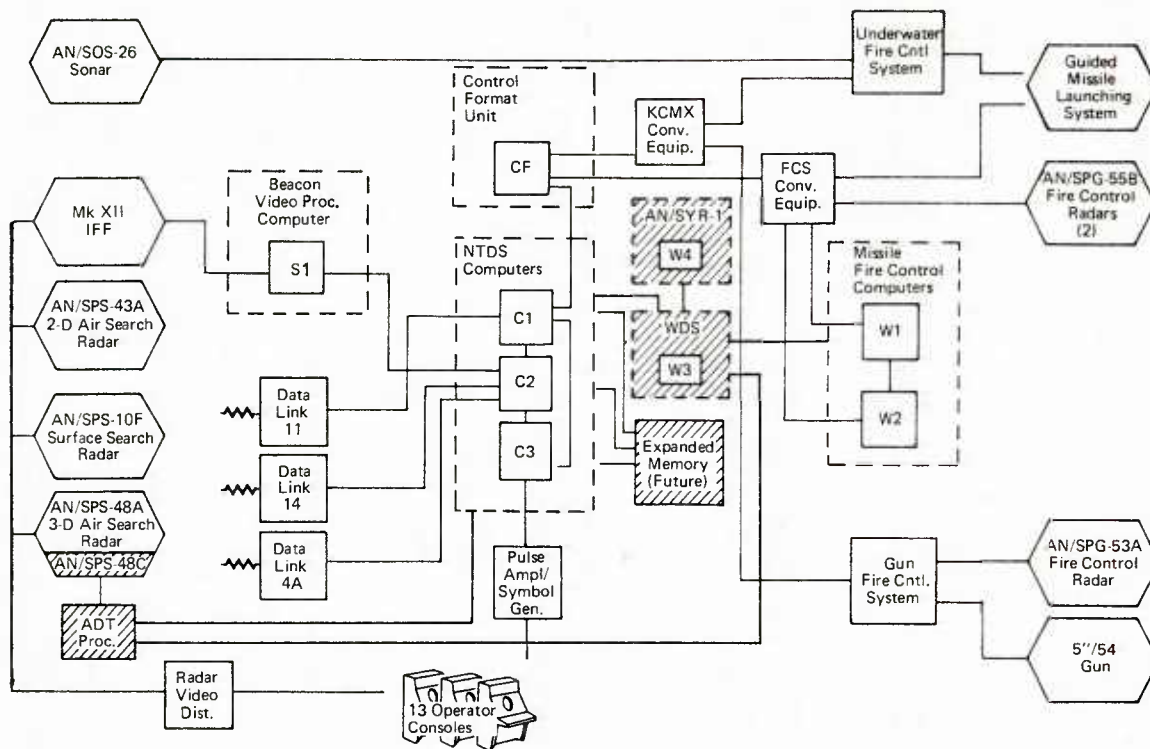


Fig. 2-1 DLG-28 Combat System

the Standard Missile 2 (SM-2) capability to DLG's 16 through 35 are indicated by shaded blocks. The characteristics of any given computer (e.g., C1) are given in Table 2-1.

2.2 COMPUTER SYSTEM ARCHITECTURE

2.2.1 Computer Characteristics

The DLG-28 combat system is supported by seven general-purpose stored-program digital computers specifically designed for use in real-time military applications. Computer characteristics and operational functions are given in Table 2-1. Any specific computer can be cross-referenced to Fig. 2-1 by using the unit designation (e.g., C1) in the table.

There are three CP-642A/USQ-20 computers aboard the DLG-28, and each communicates directly with the other two via an intercomputer input/output (I/O) channel pair. The 642A has a 32k word memory, a word length of 30 bits, and a speed of 8 μ s.

TABLE 2-1
DLG-28 COMPUTER SUMMARY

Unit	Type	Function	Pro- cessor	Memory
S1	CP-789/UYK (1218) (18 bit, 4 μ s)	Beacon video processing, auto detect and correlate, friendly identification	1	16k
S2 (future)	AN/UYK-20 (16 bit, 750 ns)	Automatic Detection and Tracking	1	40k
CF	CP-789/UYK (1218) (18 bit, 4 μ s)	Control Format Unit: interface control and data conversion	1	16k
C1, C2, C3	CP-642A/USQ-20A (30 bit, 8 μ s)	NTDS/WDS Mk 11: rate-aided tracking Threat identification and evaluation, weapon assignment and control Data link communication, air intercept control	3	32k each
W1, W2	CP-848/UYK (Mk 152) (18 bit, 2 μ s)	Missile fire control, Terrier DFCS Mk 76	2	32k each
W3 (future)	AN/UYK-20 (16 bit, 750 ns)	Weapon Direction System Mk 14, weapon assignment and control	1	64k
W4 (future)	AN/UYK-20 (16 bit, 750 ns)	Communication Tracking Set AN/SYR-1 processor, control and processing of SM-2 missile downlink data	1	64k

There are two CP-789/UYK computers aboard the DLG-28. This computer is often referred to as the Univac 1218 Military Computer or simply as the 1218. The 1218 is a medium-scale general-purpose computer used primarily in control and formatting applications. It has a 16k word memory, a word length of 18 bits, and a speed of 4 μ s.

There are two CP-848/UYK computers aboard the DLG-28, and each communicates directly with the other via an intercomputer I/O channel pair. This computer is also called the Univac 1219B (militarized version) or more frequently the Mk 152. The Mk 152 aboard the DLG-28 has a 32k word memory, a word length of 18 bits, and a speed of 2 μ s.

The general-purpose digital computers aboard the DLG-28 are supported by the following standard Navy computer peripheral equipment:

1. Mk 152 Computer Peripheral Equipment

Digital Data Recorder Mk 19 - Auxiliary storage device consisting of two magnetic tape decks.

Input/Output Console Mk 77 (two) - comprised of a paper tape perforator, a paper tape reader, a page printer, and an alphanumeric keyboard, all of which operate on a single computer I/O channel.

2. Other Computer Peripheral Equipment

Signal Data Recorder Reproducer RD-243/USQ-20(V) - magnetic tape unit with duplexed I/O for two-computer time-shared use (only one in control at a time).

Signal Data Recorder Reproducer RD-231/USQ-20(V) - paper tape unit with punch/reader capability, used primarily in debug operations.

Teletypewriter Set AN/UGC-13 (modified) - hard copy I/O device used in operations such as Link 14 data exchange etc.

2.2.2 Functional Allocation among Computers

The three CP-642A computers aboard the DLG-28 are linked together to form the major data processing element of the NTDS. This three-computer complex is designated as the NTDS unit computer. The NTDS unit computer is supported by a single computer operational program. Intercommunication among the three processors is accomplished via intercomputer I/O channels. The DLG-28 NTDS complex has primary responsibility for the combat system real-time anti-air, anti-surface, and anti-submarine combat direction functions, including tactical data correlation and evaluation. Also resident in the unit computer are the program functions necessary to support weapon direction requirements for the Terrier missile fire control system and the gun fire control system. This part of the system is designated as WDS Mk 11.

The two 1218 (CP-789) computers are required to support special-purpose processing in association with NTDS/WDS operations. One 1218 is used as a part of the BVP system. The system provides the capability for real-time automatic identification and tracking of friendly aircraft through the processing of IFF video signals. A direct interface

from this computer to one of the NTDS CP-642A's is implemented. The second 1218 is designated as the Control Format Unit (CFU) computer. The CFU computer is used to provide a single CP-642A computer interface with the Mk 152 (CP-848) computers of the Terrier missile fire control system and with the many data sources connected to the Keyset Central Multiplexer (KCMX).

Each of the two Mk 152 computers is a part of a Terrier missile fire control system. Together with its associated software, the Mk 152 is responsible for the performance of the basic computations required to engage targets with missiles, according to a designated operational mode. This includes processing required for fire control radar designation, missile launcher control, and other functions that may be required to acquire, track, and engage targets of interest.

2.2.3 Interrelation among Computers

The normal configuration of computers aboard the DLG-28 is shown in Fig. 2-1. The CP-642A computers (C1, C2, and C3) communicate directly with each other over intercomputer I/O channels. The Mk 152 computers also communicate directly with each other over intercomputer I/O channels. The 1218 BVP computer operates as a peripheral to one of the NTDS CP-642A computers, using a peripheral I/O channel. The 1218 CFU computer interfaces with a single CP-642A and a single Mk 152, using special-purpose equipment in each interface. The primary function of the special-purpose equipment is to overcome intercomputer channel limitations on the CP-642A computers.

The following combat system casualty configurations for the computers aboard the DLG-28 are available:

1. NTDS can operate at a reduced capability using only two CP-642A computers and a reduced capability operational program.
2. The BVP and CFU computers (1218's) are interchangeable through a switching arrangement.
3. Either of the fire control system Mk 152's can interface with the NTDS/WDS complex via the CFU computer.

2.2.4 Functional Interfaces with Sensors

NTDS has the primary responsibility for the tactical processing of data derived from the DLG-28 sensor systems. All sensor data (with the exception of certain IFF data) are input to the NTDS operational program via operator action at either general-purpose display

consoles or special-purpose keyset equipments. Search radar data are entered via the display system complex; electronic support measures data and sonar data are entered via the signal conversion equipments of the KCMX. Automatic (computer-to-computer) input of selected IFF data is accomplished through the BVP equipments. Figure 2-1 shows the primary computer system/sensor system interfaces for the DLG-28.

2.2.5 Functional Interfaces with Weapons

NTDS/WDS provides the primary data interface with all DLG-28 Weapon Systems. Communication between NTDS/WDS computers and all weapons is accomplished via the CFU computer. The CFU provides for direct data transfer to one of the Mk 152 computers of the Terrier missile fire control systems. This Mk 152 computer transfers the appropriate NTDS/WDS data to the other Mk 152 computer. Communication between the CFU and all other Weapon Systems is accomplished via the signal conversion equipments of the KCMX. Communication between the Mk 152 computers and associated fire control system elements is accomplished via the signal conversion equipments of the signal data converter Mk 75. Figure 2-1 shows the primary computer system/Weapon System interfaces for the DLG-28.

2.3 COMPUTER PROGRAM ARCHITECTURE

2.3.1 Naval Tactical Data System Computer Program

The DLG-28 NTDS computer program is identified as a Model III Phase 3 Computer Operational Program. All current tactical data system programs are Model III programs. The Phase 3 version is the most capable of the Model III programs. For the DLG-28, this program supports ASMD improvements and an intercomputer interface with the Terrier DFCS's.

To fulfill the various operational conditions of readiness that can exist, two types of NTDS operational programs are available for use. A Full Operational Capability Program is designed for use with all three CP-642A computers. Also, there is a Reduced Operational Capability Program designed for use with only two computers. This program is used in the event of a computer system casualty. Both programs make use of the dynamic modular replacement capability described in the next section.

2.3.2 NTDS Program Architectural Structure

The full capability NTDS operational program is referred to as a three-computer dynamic modular replacement (DMR) program. The basic module of the NTDS operational program is a subprogram element designed to perform a specific task or group of functionally related tasks, independently of other program modules. Each module is also designed to

support communications with other modules in the program without regard to the internal processing of the other modules. This communication is accomplished under executive system control and consists of either data or instruction transfer. During program development, modules are specified, designed, programmed, and tested individually.

DMR is a technique that allows an NTDS operational program to be reconfigured by the addition or deletion of certain modules from the computer core. This can be accomplished during program execution without disruption to normal tactical operations. DMR helps overcome present core constraints on the size of the operational program while providing the capability for satisfying several diverse mission requirements with a single computer program. Modules that are entered into fixed core locations at program loading are referred to as resident modules. Modules that can be dynamically added or deleted from the program during execution are referred to as transient modules. In the DLG-28 operational program, transient modules are entered into core from a magnetic tape unit.

The basic structure of all NTDS modules, resident and transient, includes a data section and an instruction section. The data section includes local data for module use only, executive interface data to be used in the transfer of Central Processing Unit (CPU) control, and a storage area for messages received from other modules. The instruction section includes a real-time instruction set and, if appropriate, may also include a periodic instruction set and/or an equipment interface instruction set. The executive system controls entry into a module's real-time, periodic, or equipment processors. Each module has a unique priority designator that indicates when CPU control will be transferred to its specific processing tasks. This designator is a part of the executive interface data contained in the module's data section.

2.3.3 NTDS Executive Program

The NTDS executive system is constructed in four functional sections. These sections are designated as Common Control (CC), Executive (EX), Intermodule/Intercomputer (IMIC), and Data Update (DU). An identical executive system resides in each of the three CP-642A computers used by the operational program, and processing in all three computers proceeds independently and simultaneously. Control is transferred to the executive system of each computer after the program has been loaded and brought on line.

The executive system Common Control section contains a common data area and an area for common processing routines. These items can be referenced by any module, as required. The common data area contains fixed length tables for storing track data, console data, and data extraction information. The common routines area contains mathematical

routines such as sine, cosine, and square root. It also contains other routines such as those required for message data packing and preset operations.

The Executive section is responsible for maintaining program control over all modules resident within its computer. It schedules all real-time and periodic references to each of these modules. Task scheduling is accomplished according to a predefined priority scheme that is based on both the module's servicing priority and whether the required module task is a real-time task or a periodic task. The Executive section is made up of three segments: a display initiation subexecutive, a real-time subexecutive, and a periodic subexecutive. The highest program priority is given to display initiation tasks. These are followed by real-time tasks and then by periodic tasks. Tasks are serviced in priority order for each Executive section cycle, so that real-time tasks are not serviced if there are any display initiation tasks to be completed, and periodic tasks are not serviced if there are any real-time tasks to be completed. Display initiation tasks are executed only in the computer interfacing with the display system complex.

The primary function of the Executive system's IMIC section is to control message transfer between modules. The IMIC section also controls computer preset procedures and provides for common data update via the Data Update section of the executive system. Intermodule message transfer, whether between modules of the same computer or between modules of different computers, can only be accomplished through the IMIC section of the Executive system.

The Executive system's Data Update section is responsible for entering, updating, and clearing data in the data stores area of the Common Control section. Messages are transferred to the Data Update section via the IMIC section. Messages from any module that are addressed to the Data Update section are sent to the Data Update sections of all three of the system's computers. The structure of the Data Update section of the Executive system is similar to that of the basic program module, and, in the program, Data Update is given the highest priority for real-time processing. This ensures that program common stores are always updated at the first available opportunity.

2.3.4 NTDS Equipment Interfaces

The NTDS computer program communicates with the following on-line equipment via the CP-642A peripheral I/O channels:

- a. Recorder Reproducer RD-243/USQ-20(V) (magnetic tape unit)
- b. Recorder Reproducer RD-231/USQ-20(V) (paper tape unit)

- c. Teletypewriter Set AN/UGC-13 (computer operations)
- d. Teletypewriter Set AN/UGC-13 (Link 14 operations)
- e. Data Display Group AN/SYA-4 (consoles and associated equipments)
- f. BVP Computer (IFF video processing)
- g. CFU Computer (digital data formatting etc.)
- h. Video Signal Simulator SM-319A/SYA-4 (test functions)
- i. Weapon Control Panel SB-1881/USQ-20 (special purpose console)
- j. Data Terminal Set OA-4477/SSQ-29 (Link 11 operations)
- k. Digital Data Communications Control Set AN/SSW-1A (Link 4A)

Communication between the NTDS computers and these equipments is accomplished under program control using the I/O instructions in the computer repertoire.

The primary tactical data interfaces supported by the computer program are with the display equipments, the CFU computer, the BVP computer, and the data link equipments (Links 11, 14, and 4A). These are shown in Fig. 2-1. The most demanding interface is that with the display complex. The NTDS program provides for generation and refresh of symbol display data at a rate sufficient to prevent "flickering" (approximately 16 times/s).

2.3.5 NTDS Module Functions

The modules of the NTDS operational program, a brief description of their primary functions, and their approximate core allocations are given in Table 2-2.

The percentage of computer time required by each module in the execution of its tasks is a function of which modules are in the system and the complexity of the tactical environment. The Executive system limits module real-time processing tasks to a maximum of 10 ms and an average of 5 ms. Module periodic tasks are limited to a maximum of 35 ms and an average of 20 ms.

2.3.6 Digital Fire Control System Computer Program

The computer operational program used in the Mk 152 computer of the Terrier Mk 76 Missile Fire Control System is designated as the

TABLE 2-2
DLG-28 NTDS MODULE DESCRIPTIONS

Module Name	Primary Function	Core Allocation
Antisubmarine	Coordination of shipboard antisubmarine warfare activities. Processes data received from underwater battery fire control system. Supports antisubmarine warfare coordinator console mode.	3850
Basic Training	Simulation of a realistic tactical environment for training purposes. Includes simulation of radar returns for display on consoles.	3150
Beacon Video Processor	Provides interface between NTDS program and BVP equipment. Supports BVP tracker console mode.	4800
Combat Systems Operability Test	Processes and prints out selected data extraction events.	2900
Control Format Interface	Provides interface between NTDS program and both the KCMX and the missile fire control computers.	900
Data Update (CCEXIMDU)	Includes Executive, Intermodule/Intercomputer, Data Update, and Common Control data sections. Functions as NTDS executive system.	3900
Data Extraction	Controls the extraction and recording on magnetic tape of system operational data.	1300
Display	Provides interface between console operators and the NTDS program via the display subsystem. Supports all console displays and pushbutton operations.	11350
Dynamic Modular Replacement	Master provides for modification of program configuration. Slave supports bookkeeping functions in non-master computers.	3050 100
Electronic Warfare	Provides interface between NTDS program and Electronic Warfare (EW) data entry devices. Supports an EW console mode.	11900
Threat Evaluation	Provides estimate of relative threat for all system tracks.	1750

TABLE 2-2 (cont'd)

Module Name	Primary Function	Core Allocation
Tracking	Performs tasks associated with rate-aided tracking based on track position data entries. Supports detector/tracker and track supervisor console modes.	9900
Weapon Assignment	Provides solutions to force and ownship tactical problems and provides processing for engagement orders. Supports ship weapon coordinator's console mode.	10100
Weapon Control	Controls the exchange of order and status information between NTDS and the missile and gun systems. Supports the fire control system coordinator and engagement controller console modes.	7100
Height	Processes height inputs and a limited number of size inputs from consoles.	600
Height/Size	Processes air-track height and size data inputs from consoles.	1650
Identification	Processes track identification data received from consoles and from other modules such as the BVP. Supports the identification console mode.	1950
Intercept Control	Supports intercept controller tasks for vectoring interceptors to attack positions. Calculates trial intercepts.	5300
Intercept Vector	Supports intercept controller tasks for vectoring interceptors to attack positions. Calculates pursuit or collision geometries.	2900
Link 4A	Provides an interface between the NTDS program and the Link 4A communications equipments.	950
Link 14	Selects and formats NTDS tactical data and supplies it for broadcast to non-NTDS ships in the force.	2450
Resident Control	Provides utility processing routines such as inspect, change, clear, etc.	1850
Surface Operations	Provides solutions to trial maneuver problems for closest point of approach. Maintains position and velocity for ownship.	2350
System Tracker/Link 11	Provides processing for Link 11 data exchange with other units.	6950

Universal Fire Control Computer Program. It operates with the Mk 76 Mod 7 and Mod 8 Terrier fire control systems, as well as the DLG-28 Mk 76 Mod 6 system. There is an identical DFCS computer program resident in the Mk 152 computer of each missile fire control system. Communication between the two computer programs is accomplished over Mk 152 intercomputer I/O channels.

2.3.7 DFCS Program Architectural Structure

The DFCS computer program is a modular program. Modular elements are designated as subprograms. The Universal Fire Control Computer Program consists of 34 subprograms, identified as either Executive and Control subprograms (11) or Data Processing subprograms (23).

A subprogram is designed to accomplish a specific task or a set of functionally related tasks. A task is an operation (or group of operations) that is functionally independent of other program operations. An example of a task is "Perform Trigonometric Conversion." This is a task of the Common Processing subprogram. The functions of a subprogram are defined by the tasks to be performed by that subprogram. A task may be further defined by the individual functions that are associated with its processing. Each subprogram having independent tasks to perform is designed with its own executive subroutine to sequence to its tasks, as appropriate. The overall program is then controlled by an executive subprogram that contains higher level control and timing logic.

Of the 34 DFCS subprograms, about 17 are used in the processing of tactical operations. The remaining subprograms are used primarily in data extraction or system test operations.

2.3.8 DFCS Executive Program Functions

The DFCS computer program is designed such that tactical subprograms are selected and executed according to specific predefined modes of Fire Control System (FCS) operation. There are nine primary operational modes defined; eight are designated as tactical modes, and one is designated as the System Test Mode. Tactical mode processing requires the use of 17 subprograms including the Executive and FCS Control subprograms.

The eight tactical modes and their primary functions are as follows:

1. Air Ready — provides for the setup of an FCS standby condition, wherein all elements are in a stowed position but are ready for immediate response.

2. Designation — provides for initial positioning of the radar beam to a point in space corresponding to the designation, provides for automatic selection and execution of the proper director search pattern, and provides for response to input control and status signals while the director is attempting to acquire the target.
3. Air — executes processing functions for normal operations in an air mode including director control, target position prediction, launch missile orders, engageability calculations, etc.
4. Shore — executes functions that are required in the missile engagement of shore targets.
5. Surface One Director — executes functions appropriate to the engagement of surface targets with a beam-riding missile.
6. Surface Homing — executes functions that are required in the engagement of surface targets with missiles in the surface homing mode.
7. Self-Defense CBT — executes functions appropriate to engagements using the continuous boat track (CBT) capability.
8. Self-Defense SSE — executes functions appropriate to engagements using the sector scan engagement (SSE) capability.

Subprogram sequencing and execution for these tactical operational modes is controlled by the FCS Control subprogram. This subprogram is in turn under the control of the DFCS Executive subprogram. These two subprograms perform the tactical processing executive functions.

The major tasks of the Executive subprogram include defining when the FCS Control subprogram is to be executed, initiating and controlling the clock cycle time, and maintaining time correlation with the NTDS computer system. The FCS Control subprogram has only one task — to control when the subprograms for which it is responsible are to be executed. On the basis of system status signals, a mode determination subprogram establishes the correct mode to be executed. The FCS Control subprogram then calls the required subprograms for that mode.

The basic execution rate of the FCS Control subprogram is controlled by a rigidly defined Executive subroutine. The execution rate

for subprograms in the Designation and SSE modes is 32 times/s. The execution rate for all other subprograms is 16 times/s, except for the Engage subprogram which is 2 times/s. All of these execution rates are derived from a basic 32-per-second rate through a counting process in the FCS Control subprogram. A brief description of the subprogram elements is given in Section 2.3.10.

This section has described executive processing for tactical mode operations. A similar processing routine is used for system maintenance test (SMT) operations. These are accomplished under control of the SMT Control subprogram in conjunction with the Executive subprogram.

2.3.9 DFCS Equipment Interfaces

The DFCS computer program communicates with the following on-line equipments:

1. Signal Data Converter Mk 75
2. Digital Data Transfer Unit (DDTU) (part of Signal Data Converter)
3. Digital Computer Mk 152 (other FCS)
4. Digital Data Recorder Mk 19 (magnetic tape unit)
5. Input/Output Console Mk 77 (PTU, printer, keyboard)
6. Control Panel Mk 298 (switching etc.)
7. RF Simulator System

Communication between the DFCS computer and these equipments is accomplished under program control using the input/output instructions in the computer repertoire.

The primary tactical operational data interfaces, as shown on Fig. 2-1, are the NTDS/WDS interface and the fire control radar and launcher interfaces. The DFCS computer program operates on inputs received from NTDS/WDS via the CFU and from the fire control radar and missile launching system via the Signal Data Converter. After the appropriate processing is accomplished in response to these inputs, the DFCS program generates outputs of designation position and search and surveillance patterns. When appropriate, the program also solves the fire control problem to derive outputs of launcher position and rate orders, missile orders, target angular rates, target present position, and engageability parameters. Engageability and DFCS status are provided to NTDS/WDS for use in combat direction/weapon direction operations. The DFCS interface with NTDS/WDS is accomplished through a

single DFCS computer. That computer forwards NTDS/WDS information to the other DFCS computer over a direct intercomputer interface.

2.3.10 DFCS Subprogram Functions

The DFCS computer program is divided into an Executive subprogram, 2 mode control subprograms, 8 test control subprograms, 22 data processing subprograms, and a common processing subroutines subprogram. The subprograms of the DFCS operational program, a brief description of their primary functions, and their approximate core allocations are given in Table 2-3.

TABLE 2-3
DLG-28 DFCS SUBPROGRAM DESCRIPTIONS

Subprogram Name	Primary Function	Core Allocation
Air Ready	Provides for positioning director to stow position, generating launcher stow orders, etc.	200
ASMD Readiness	Supports a system maintenance test.	900
Automatic Monitoring	Provides display interface for use in system monitoring.	870
CFU Interface	Provides for program interface with CFU computer.	1250
Common Processing	Provides a collection of mathematical equations and logical processes designed to solve recurring program operations.	1130
Data Extraction	Provides magnetic tape storage for selected quantities.	1460
Designation/Search	Performs major program functions for all designation or search modes.	2800
DFCS UFCCP Executive	Provides overall system executive functions. Establishes when FCS Control subprogram is executed, determines when each program clock cycle is initiated and controls duration, and provides for time correlation with NTDS.	30
Engageability and Display	Combines computation of target engageability and a miscellany of display functions that require low update rates.	610
FCS Control	Controls the execution of 17 subprograms (primarily tactical subprograms).	220
Fire Control Parameters	Supports a system maintenance test.	2260
Firing and Casualty Readiness	Supports a system maintenance test.	1050
Interbattery	Not applicable to DLG-28	430
Intercomputer	Provides for data transfer between two Mk 152's.	430
IOC Display	Provides program output interface with I/O console.	410
Launcher/Missile Orders	Computes launch doctrine and orders for the launcher and missile	1380
Mode Determination	Provides for evaluation of major computer mode-determining logic and makes results available for internal and external use.	830
Relative Alignment	Supports a system maintenance test.	4950

TABLE 2-3 (cont'd)

Subprogram Name	Primary Function	Core Allocation
RF Simulator Control	Supports a system maintenance test.	1140
SDC Input	Formats data from Signal Data Converter for use by program.	590
SDC Output	Provides program output interface with Signal Data Converter	400
Secondary Air Search	Supports a system maintenance test.	1240
Shore	Computes functions associated with shore mode.	230
SMT Control	Controls the execution of 11 subprograms (primarily SMT subprograms).	350
SMT Input Processing	Interprets and converts data from I/O console for use by program.	1390
Surface One-Director	Computes functions associated with surface mode.	40
Surface/Shore Mode Readiness	Supports a system maintenance test.	2300
Target Generation	Supports a system maintenance test.	680
Target Position and Prediction	Calculates target position quantities and predicts certain future target positions.	600
Tracking	Provides for control of director angular position in all modes for which one or both axes are to be positioned on the basis of 55B derived target data.	1190
True Alignment and Transmission	Supports a system maintenance test.	2300
UD1230 Input Processing	Not applicable to DLG-28.	490
UD1230 Output Processing	Not applicable to DLG-28.	550
Weapon System Parameters	Supports a system maintenance test.	2060

2.4 SOFTWARE DEFINITION, DESIGN, AND IMPLEMENTATION

2.4.1 NTDS Program Definition, Design, and Implementation

The NTDS computer operational program for the DLG-28 is an in-service program that has evolved through a series of design improvements. Most of the definition, design, and implementation activities associated with this program development have been related to the modification of an existing program. The selected modular structure of the program allows modification of specific functional areas with minimum impact on other functional areas. This is a necessary and desirable feature since the NTDS program must be frequently modified to accommodate new requirements that result from the implementation of new equipment or revised operating concepts.

The definition phase for program modification is normally undertaken as a joint effort between the maintenance agent (FCDSSA(DN)) and an agent for the activity sponsoring the modification. The requirements associated with the modification are documented in appropriate system-level specifications. Where the modification results in new requirements for an interface with the NTDS computer, a jointly developed and jointly promulgated Interface Design Specification is issued. Continuity of program design, as well as technical and operational feasibility, is assured by the participation of the maintenance agent in the requirements definition phases of program modification.

To support effective implementation of new design requirements, FCDSSA(DN) has prepared a comprehensive Program Production Procedures Manual (PPPM). This four-volume document provides guidance in all phases of program production through delivery and maintenance.

Program modifications coded in machine language for the CP-642A are produced via the CS-1 compiling system, an early version of one of the Navy's current standard compilers (CMS-2). Where low-level language code is more appropriate to implementation requirements, its use is allowed (e.g., executive programs, input/output, etc.).

2.4.2 DFCS Program Definition, Design, and Implementation

The definition phase of the DFCS design effort established computer program performance requirements for the DFCS. These requirements were developed to support a specified level of operational capability for the missile Weapon System. The requirements definition task included an analysis of known limitations and deficiencies in existing analog systems.

An ADM of the DFCS was developed by the Applied Physics Laboratory. The ADM performed the tactical functions associated with the

operations of the fire control system and demonstrated the improvement in tactical performance that could be achieved through implementation of a DFCS.

As a result of the success of the ADM, the Naval Ordnance Systems Command (NAVORD) tasked the Applied Physics Laboratory and Automation Industries/Vitro Laboratories to develop a production version of the DFCS. Using the ADM as a baseline, APL defined Performance and Capability Requirements (XWS 13058) for the DFCS. The production version of the DFCS program was designed and coded by Vitro and documented in Weapon Specification XWS 9500. This effort included the design and implementation of maintenance test programs and a data extraction capability. Documentation for the DFCS computer program was prepared in accordance with the guidelines of NAVORD XWS 8506, Requirements for Digital Computer Program Documentation.

The DFCS program was developed using a top-down design philosophy. The program was easily organized into independent functional areas. Functional diagrams and flowcharts were prepared as a part of the design documentation. The TRIM III assembly language was used for the program.

The success of the design and implementation effort can be attributed in part to the extensive interaction between those responsible for defining program performance requirements and those responsible for program design implementation. This interaction is addressed in more detail in Section 2.5.2.

2.5 SOFTWARE VALIDATION AND INTEGRATION

2.5.1 NTDS Program Validation and Integration

The validation and integration of NTDS program modifications is the responsibility of the NTDS life-cycle maintenance agent, FCDSSA(DN). FCDSSA(DN) has developed a considerable capability for test and acceptance of NTDS computer programs. This capability includes a test department whose function is to plan, control, and execute thorough testing of NTDS computer programs. Extensive use is made of on-site equipments, including a DLG-28 Combat Direction System mock-up. The DLG-28 mock-up with appropriate simulation support provides the capability to test program designs in an operational environment.

Test activities have been allocated to four major test areas: program module tests, computer integration tests, computer system tests, and operational program functional checkouts. To ensure that performance requirements are supported by program design, FCDSSA participates in the preparation of test plans, test specifications, and test procedures. Details of test management procedures are provided in Volume IV of the PPPM.

Performance deficiencies detected in either the development or maintenance phases of a program are documented in standardized Trouble Reports. These can originate from three sources: developing agency, procuring agency, or the Fleet. Trouble reports are coded according to severity and are forwarded to the appropriate activities for action. Procedures for Trouble Report preparation are included in the PPPM.

2.5.2 DFCS Program Validation and Integration

System test and integration activities for the DFCS program were the responsibility of the Applied Physics Laboratory. Since APL was also responsible for the definition of DFCS program performance requirements, a system of checks and balances for the definition, design, and validation phases of program development was achieved. Program design activities supported by Vitro provided information that assisted in completing performance requirements specifications and in assuring that performance requirements were consistent and valid. These performance requirements in turn provided the standard by which program design was measured. Detailed certification test plans and procedures were developed for use in testing phases of the DFCS program development. Initial testing was accomplished at the subprogram or module level. This was followed by system-level testing at several test site facilities. These facilities were located at APL, Naval Surface Weapons Center (NSWC) Dahlgren, and the Guided Missile School (GMS) at Dam Neck.

The APL Land-Based Test Site (LBTS) consisted of a Mk 152 digital fire control computer, SPG-55B radar set, Mk 75 Signal Data Converter, UYA-4 PPI display console, and a Univac 1218 (CP-789) computer. The 1218 had a target generator and provided simulated inputs to the DFCS computer. Live radar inputs were also available. The 1218 generated displays for a UYA-4 console that was used as a test input and monitor console. The 1218 performed data extraction to a magnetic tape unit. The test procedures would typically require the operator to set up specific inputs and look for specific outputs either on his console or in the extracted data.

The NSWC Dahlgren facility had a wraparound tester that also used a second computer and a UYA-4 to generate test targets and monitor outputs. No live radar data were available. Testing at NSWC could be performed manually as at APL, or automatically. In the automatic tests, a stimulus magnetic tape was generated off-line. The Mk 152 program was modified to read this tape and record the results of the DFCS processing. The answers were then compared with answers that had been computed off-line. This was found to be a useful testing procedure.

The final step in system testing was to verify system operation at GMS Dam Neck by placing the DFCS in an operating combat system configuration. This included interfacing the DFCS to an NTDS/WDS combat direction system and a fire control radar set.

Each of the testing techniques was found to be useful in DFCS program validation. In general, the testing and integration tasks proceeded smoothly with no serious problems or delays.

Integration activities for the DFCS were placed under tight control through the establishment of a Digital Steering Committee (DSC). This committee was chaired by Naval Ship Weapons Systems Engineering Station (NSWSES) and included representatives from NAVORD, APL, Vitro, NSWC Dahlgren, FCDSSA(DN), and Fleet Missile Systems Assessment and Evaluation Group (FMSAEG). The activities of this committee encompassed all phases of program development. The DSC proved to be a valuable asset to the DFCS program development effort. Major contributions of the DSC were in the general coordination and management of integration tasks, the resolution of design conflicts, and the review and verification of specifications and other documentation.

2.6 SOFTWARE ACQUISITION MANAGEMENT ORGANIZATION AND METHODS

2.6.1 NTDS Acquisition Management

The organizations involved in software acquisition for the DLG-28 NTDS Computer Operational Program are listed in Table 2-4.

TABLE 2-4
DLG-28 NTDS ACQUISITION MANAGEMENT

Program Manager	FCDSSA(DN)
System Contractor	FCDSSA(DN)
Software Contractor	ISSI
Type Contract	Level of Effort
Program Status	Deployed
Maintenance Agent	FCDSSA(DN)
Software Deliverables	Operational Program and Program Documentation
Validation Agent	FCDSSA(DN)
Integration Agent	FCDSSA(DN)

As is apparent from this list, FCDSSA(DN) has primary responsibility for the DLG-28 NTDS software. This responsibility includes acquisition management as appropriate to implementation of program modifications. Both the management organization and acquisition methods are well established and are described in detail in Volume I of the PPPM.

The NTDS operational program for the DLG-28 has undergone several major modifications since it was turned over to FCDSSA for life-cycle maintenance. The present program is designated as a Model III Phase 3 Program. A change in Model number accompanies a change in digital data link requirements for tactical data system programs. A change in phase number results from modifications to a model which incorporate new operational capabilities. The Model III Phase 3 program is the most capable of currently implemented DLG programs. A Model IV Computer Operational Program is presently being developed for the DLG-28 class ship.

Acquisition management factors that have been found beneficial to software development include an early data base design freeze and the use of an on-site contractor working under a level-of-effort contract. FCDSSA(DN) maintains a day-to-day working relationship with its contractors. Both Navy and contract personnel are experienced and knowledgeable in DLG combat system operational requirements, and this capability is a definite asset to the implementation of program modifications. In general, problems are more easily identified, and required actions are taken earlier than would be possible under other types of contractor support.

2.6.2 DFCS Acquisition Management

The various organizations involved in the DFCS software acquisition are listed in Table 2-5.

DFCS acquisition management was a primary responsibility of the DFCS DSC. The DSC exercised control over program configuration, development, test, and integration. The DSC was involved in the review cycle for all program documentation. Acquisition procedures followed an orderly software development process as described in earlier sections. Initially, program performance requirements were defined and specified in XWS 13058. These provided the basis for the specification of program design requirements in XWS 9500. Both of these documents served as management tools for subsequent program implementation phases. Other documentation prepared during program acquisition included a computer program specification package, a common data base design document, a computer operator's manual, a computer program evaluation test plan, and a fire control system test plan.

TABLE 2-5
DLG-28 DFCS ACQUISITION MANAGEMENT

Program Manager	NAVSEA 6541 (Terrier)
System Contractor	APL (ADM) Vitro (Production)
Maintenance Agent	NSWC Dahlgren
Software Deliverables	Operational Program and Program Documentation
Validation Agent	APL/NSWC Dahlgren (approved NSWSES, NAVSEA)
Integration Agent	APL
In-Service Engineering Agent	NSWSES

In general, the acquisition task was accomplished effectively and with few major problems. Factors contributing to the overall success of the development effort were the activities of the DSC and the good working relationships (both formal and informal) among the above-listed organizations.

2.7 OPERATIONAL SOFTWARE MAINTENANCE

2.7.1 NTDS Program Maintenance

After production versions of the DLG operational program were successfully deployed, FCDSSA(DN) assumed the life-cycle maintenance responsibility. The transfer of responsibility within FCDSSA(DN) was orderly due mainly to FCDSSA(DN) being involved from the program's inception. Further modifications, including Model IV, will be supervised by FCDSSA(DN) personnel. Since the initial program was taken over for maintenance, the program has developed almost entirely under the auspices of FCDSSA(DN).

2.7.2 DFCS Program Maintenance

NSWC Dahlgren is the agent responsible for the DFCS computer program maintenance. It receives assistance in this effort from NSWSES, the designated In-Service Engineering Agent. Vitro also provides support when requested.

There were no particular problems in transferring the program to the maintenance agent. The transfer was aided by the fact that NSWC had participated in the software validation phase at the APL LBTS.

A standard TRIM III language was used to develop the program, and NSWC had a compiler available. The documentation provided to NSWC was adequate.

2.8 HIGHLIGHTS

DLG-28 was the first operational (1966) combat system that integrated the tactical data system functions with weapon direction system functions resulting in WDS Mk 11. Weapon Systems requirements were identified by both the NTDS Program Manager and the Weapon Systems manager in mutually acceptable requirements documents. (MP1)

An on-site level-of-effort contract allowed close working relationships between the NTDS contractor and the development agent. Problems were easily identified, and required actions were taken earlier than would have been possible otherwise. (MP1,MS2)

The NTDS system can operate at reduced capacity with only two computers; the DFCS system can operate at reduced capacity with only one computer. (SE1,SE2)

The Dynamic Modular Replacement (DMR) technique for read-in of alternate program modules to facilitate different combat system warfare requirements was developed for these ships. (SE2)

An early freeze of Data Base design provided stable program development control. (SE3)

Common software modules were developed to provide compatibility among ships of the same class but with different equipment suites. (SE3)

The DFCS program was developed and validated using a land-based test site at the developer's site (APL). (IP3)

Both Navy and contractor personnel were experienced and knowledgeable in DLG combat system operational requirements. This enhanced development by exploiting proven development techniques and avoiding previous mistakes. (MS2)

A single agent was responsible for life-cycle maintenance as well as modification programming; this allowed an orderly transition from an existing program to a more capable program. (MS3)

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3. DDG-9 COMBAT SYSTEM

3.1 GENERAL SYSTEM DESCRIPTION

DDG-9 (USS Towers) is one of 29 Guided Missile Destroyers armed with the Tartar or Standard Missile 1 (SM-1) Medium Range (MR) missile Weapon System. DDG's 2 through 24 were "new construction," whereas DDG's 31 through 36 are converted Sherman/Mitscher DD's. Four of the DDG's, the C. F. Adams Class, are provided with a Tactical Data System (TDS).

The general mission of the Guided Missile Destroyer is to operate offensively with strike forces, to operate with hunter/killer groups, to support amphibious assault operations, and to screen support forces and convoys against submarine, air, and surface threats.

The major subsystems of the DDG-9 combat system are the sensor system, the combat direction system, and the missile, gun, electronic warfare, and antisubmarine warfare Weapon Systems. These subsystems are integrated into the total combat system to support tactical operational requirements for target detection, tracking, identification, evaluation, and assignment to weapons for a controlled engagement.

3.1.1 Sensor System

The primary capability for detection, tracking, and identification of air and surface targets is provided by the search radar system and its associated identification friend or foe (IFF) equipments. The DDG-9 is equipped with a surface search radar (AN/SPS-10C), a three-coordinate long-range air-search radar (AN/SPS-39A), and a two-coordinate long-range air-search radar (AN/SPS-29E). The IFF capability for the DDG-9 is provided by the Automatic Identification Mk XII System (AIMS).

Video processing equipment designated as the Beacon Video Processor (BVP) operates on IFF data to provide an automatic identification capability for friendly aircraft. The BVP is also supported by a section of the combat direction system computer operational program.

The primary capability for subsurface target detection and tracking on the DDG-9 is provided by a sonar detection and ranging set (AN/SQS-23).

The electronic support measures (ESM) functions of the DDG-9 are provided by an electronic warfare system (AN/SLQ-26) and an ESM receiver group (OR-45/SLQ-19).

3.1.2 Combat Direction System

Combat direction functions on the DDG-9 are provided by the TDS. The primary elements of the TDS are a data processing system, a display system, data communications equipments, and miscellaneous data conversion equipments.

The data processing system includes a general-purpose digital computer (AN/UYK-7), associated software, and various peripheral devices. The communications system includes equipments that provide the capability for the DDG-9 to participate in data exchange over data Link 11 (computer-to-computer data exchange with remote units).

3.1.3 Weapon Systems

The primary Weapon System aboard the DDG-9 is the Tartar guided missile system. There are two Missile Fire Control Systems (MFCS) (Mk 74 Mod 8); each is supported by a general-purpose digital computer (Mk 152) and associated software. Missiles are launched from a guided missile launching system (GMLS) (Mk 11 Mod 0).

The DDG-9 gun Weapon System consists of a gun fire control system (Mk 68 Mod 8) and two 5"/54 gun mounts.

Antisubmarine warfare functions are supported by an underwater battery fire control group (Mk 111), ASROC missiles launched from an ASROC launcher (Launching Group Mk 16), and two torpedo tubes.

Electronic warfare functions are supported by an electronic countermeasures (ECM) set (AN/ULQ-6B).

3.1.4 Acquisition History

The DDG's carrying the TDS have also been improved by the addition of Digital Fire Control Systems (DFCS). Additional improvements will include Integrated Automatic Detection and Tracking (IADT) by the addition of AN/SYS-1 IADT processors.

The development of DFCS's for the DDG's was initiated in 1964. The initial design was based on the use of the CP-789/UYK. As development progressed, the capacity of the CP-789 was found to be inadequate, and the CP-848/UYK (Mk 152) was used. First installation was on DDG-16 in 1971, with all the DDG's to be completed by 1976.

The DDG TDS program was initiated by NAVORD (Project Manager) in 1969. Naval Ship Engineering Center (NAVSEC) was designated as the Program Development Agency (PDA), with Fleet Combat Direction System

Support Activity, Dam Neck (FCDSSA(DN)) as the TDS agent and Univac the prime contractor for software development. Naval Surface Weapons Center (NSWC) (Dahlgren) was selected as the NAVORD agent for the Tartar Weapon Direction System (WDS) with Raytheon as the prime software contractor.

In 1970, software development was begun. Upon completion of an 18-month test phase at Mare Island (November 1971-1973), a performance test (DS 659) was conducted by Operational Test and Evaluation Force (OPTEVFOR) in mid-1973 at Mare Island. Final Formal Test and Acceptance by the Navy, conducted at FCDSSA(DN), culminated in a 24-hour endurance trial in early 1974. The Navy accepted the Operational Program (Version 0) on 1 April 1974. Version 2 has now been accepted. Three TDS DDG's (12, 15, and 21) have recently completed a successful 7-month tour in the Pacific. The TDS program is now in maintenance phase at FCDSSA(DN).

In the DDG-2 Class Upgrade Program, these ships will be the first to incorporate an IADT system, the AN/SYS-1. This system will initially provide IADT based on data from the AN/SPS-52B(Mod), AN/SPS-40C/D, and the AN/SPS-58C. Design goals for the future include the incorporation of all onboard sensors into the IADT system.

The design of the combat system for the DDG-2 Upgrade will use standard general-purpose consoles and computers throughout the system. The responsibility for the development and implementation of the complete combat system for the DDG Upgrade has been given to NAVSEA 6542.

3.1.5 System Diagram

A system block diagram of the DDG-9 combat system is shown in Fig. 3-1 indicating the functional relationships among the primary system elements. The shaded blocks designate the functional changes for the recently approved DDG Upgrade Program scheduled for 23 ships (DDG's 2 through 24). The characteristics of any given computer (e.g., W1) are given in Table 3-1.

3.2 COMPUTER SYSTEM ARCHITECTURE

3.2.1 Computer Characteristics

The DDG-9 combat system is supported by three general-purpose stored-program digital computers specifically designed for use in real-time military applications. These are an AN/UYK-7 and two CP-848/UYK computers, both manufactured by Univac. Computer characteristics and operational functions are given in Table 3-1 for DDG-class ships.

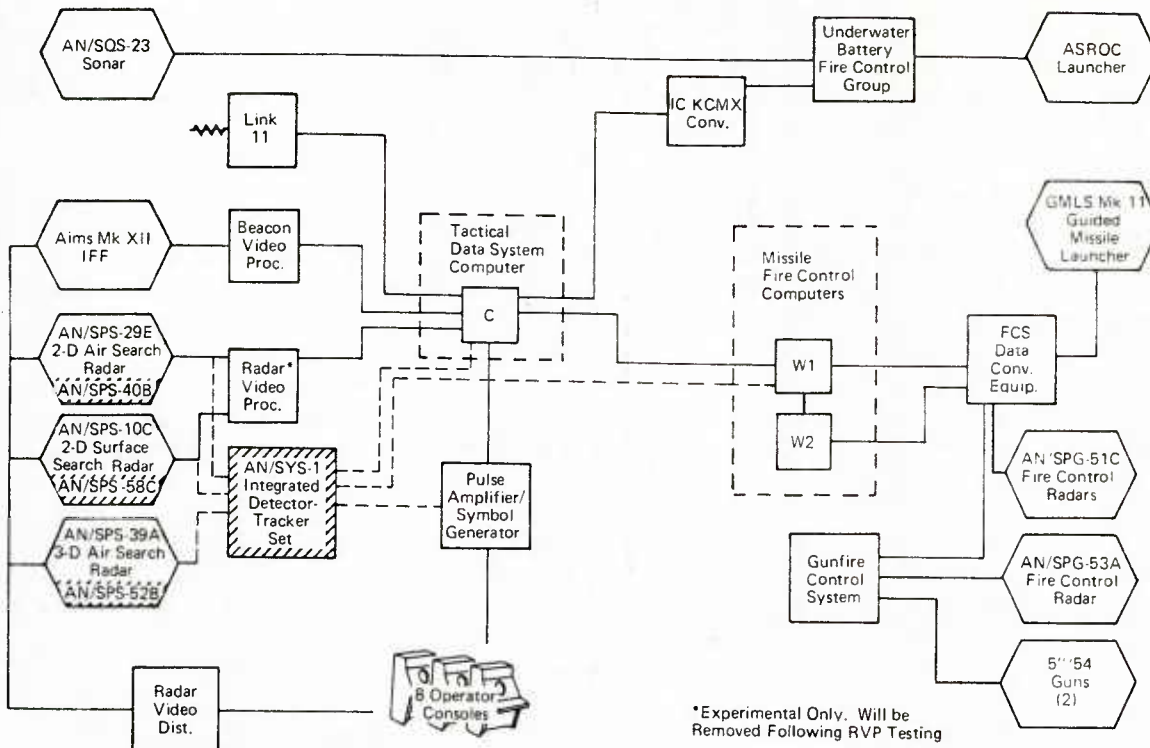


Fig. 3-1 DDG-9 Combat System

TABLE 3-1
DDG-9 COMPUTER SUMMARY

Unit	Type	Function	Pro- cessor	Memory
C	AN/UYK-7 (32 bit, 1.5 μ s)	Tactical data processing: detect and track from beacon and 2D radar data, rate-aided track, threat identification and evaluation, weapon assign- ment, link communication	1	48k
W1	CP-848/UYK (Mk 152) (18 bit, 2 μ s)	Missile fire control/weapon direction	1	48k
W2	CP-848/UYK (Mk 152) (18 bit, 2 μ s)	Missile fire control/weapon direction	1	48k

The AN/UYK-7 makes use of modular construction and consists of a central processor, an input/output (I/O) controller, an I/O adapter, a power supply, and three memory modules of 16k words each. The UYK-7 has a word length of 32 bits and a memory cycle time of 1.5 μ s.

The two CP-848/UYK computers communicate directly with each other via an intercomputer I/O channel pair. The CP-848 computer is also called the Univac 1219B (militarized version) or more frequently the Mk 152 Mod 1. The Mk 152 aboard the DDG-9 has a 48k word memory, a word length of 18 bits, and a memory cycle time of 2 μ s.

The general-purpose digital computers aboard the DDG-9 are supported by the following standard Navy computer peripheral equipments:

1. AN/UYK-7 Computer Peripheral Equipment

Data Exchange Auxiliary Console (DEAC) (OJ-172/UYK) — comprised of two magnetic tape transports, a paper tape punch and reader unit, and a teletype keyboard printer unit, all of which operate on a single computer I/O channel.

2. Mk 152 Computer Peripheral Equipment

Input/Output Console Mk 77 — comprised of a paper tape perforator, a paper tape reader, a page printer, and an alphanumeric keyboard, all of which operate on a single computer I/O channel (Univac 1532).

For conditions of Mk 77 casualty, the magnetic tape unit of the DEAC can be used to load the Mk 152 operational programs.

3.2.2 Functional Allocation among Computers

The AN/UYK-7 computer is the major element of the TDS, which has the primary responsibility for DDG-9 combat direction functions. The UYK-7, supported by a tactical operational program, provides the data processing capability required to collect, correlate, and evaluate track data input from combat system sensor equipments. Through operator interaction with the program via a display system complex, the TDS provides the operational capabilities required to effectively respond to hostile tactical environments. In addition to its primary combat direction functions, the TDS is also responsible for data processing associated with the Radar Video Processor (RVP) and the BVP.

Each of the two Mk 152 (CP-848) computers is a part of a Tartar missile fire control system. Together with its associated software, the Mk 152 is responsible for the performance of the basic computations required to engage targets with missiles, according to a designated operational mode. This includes processing required for fire control radar designation, missile launcher control, and other functions that may be necessary to acquire, track, and engage targets of interest. Also resident in the Mk 152 computer are the program functions necessary to support weapon direction requirements for the Tartar missile fire control system and the gun fire control system. This part of the system is designated as WDS Mk 13 Mod 1.

3.2.3 Interrelation among Computers

The interface configuration of DDG-9 computers is shown in Fig. 3-1. The two Mk 152 computers communicate directly with each other over intercomputer I/O channels. The TDS UYK-7 computer communicates with one of the Mk 152 computers over an intercomputer I/O channel pair. This Mk 152 is designated as the "primary" missile fire control system computer and is the one having responsibility for processing weapon direction functions.

A switching arrangement among the three computers allows either Mk 152 to operate as the primary missile fire control computer. This provides a casualty capability in the event of the loss of the Mk 152 designated as the primary computer. A limited capability for driving consoles can be supported by the WDS area of the primary Mk 152 in the event of an AN/UYK-7 casualty.

3.2.4 Functional Interfaces With Sensors

The TDS has the primary responsibility for the tactical processing of data derived from the DDG-9 sensor systems. Search radar data are input to the TDS operational program manually via operator action at a general-purpose display console. Automatic input of selected IFF data is accomplished through the BVP equipments. ESM data and sonar data are entered via the signal conversion equipments of the Integrated Circuit Keyset Central Multiplexer (ICKCMX). Figure 3-1 shows the major computer system/sensor system interfaces for the DDG-9.

3.2.5 Functional Interfaces With Weapons

The TDS also has the primary responsibility for initiating and controlling weapon responses to threats. Communication between the TDS UYK-7 and both the Tartar missile system and the gun system is accomplished via the primary Mk 152 computer. This computer transfers the appropriate TDS data to the other Mk 152. Communication between the Mk 152 computers and the associated weapon fire control system elements is accomplished via the signal conversion equipments of the Signal Data Converter Mk 72. Communication between the TDS UYK-7 and both the electronic warfare and antisubmarine warfare systems is accomplished via the signal conversion equipments of the ICKCMX. Figure 3-1 shows the primary computer system/Weapon System interfaces for the DDG-9.

3.3 COMPUTER PROGRAM ARCHITECTURE

3.3.1 Tactical Data System Computer Program

The DDG-9 TDS computer program is identified as a Model III Computer Operational Program. Operational programs of a given model communicate via digital data links with other TDS programs of the same model. All current Navy TDS programs in operational use are Model III programs.

3.3.2 Tactical Data System Program Architectural Structure

The TDS program structure is highly modular in form. Each module consists of a local data segment and an instruction segment containing three logical entry points for priority, message, or periodic processing requirements. A bare minimum of three modules, collectively referred to as the "Common Program," is required for program cycling. Other individual modules provide individual functions, such as tracking, beacon video processing, or radar video processing, and may be operator selected to form the desired operational program configuration. As individual modules are called into the computer from program tape, the instruction and data segments are respectively placed in low and high core addresses to take advantage of UYK-7 memory accessing time savings.

UYK-7 computer architecture is also utilized to separate program executive processing from other processes by executing the Common

Control module instructions while within the UYK-7 Executive state. All I/O functions, message scheduling, and module calls are performed within the Common Control module in the Executive machine state. Other processing is performed using the Task state registers and Task operating mode of the UYK-7.

A common data base and assemblage of utility routines (other than I/O) are provided by the Common System module. This module may be accessed by any other module in the program.

3.3.3 Tactical Data System Executive Program

The Executive function of the TDS program provides for all program interrupt handling (including clock, I/O, and function requests from Task state processing), scheduling, and module calling (priority, message, and periodic).

In essence, the Executive is entirely interrupt-driven. I/O requests and message packing are performed from Task state programs by setting the appropriate interrupt codes and causing an internal interrupt to enter the Executive state where the desired function is performed. Normal returns to the executive from module processing (Task state) are performed in a similar manner.

3.3.4 Tactical Data System Equipment Interfaces

The TDS computer program communicates with the equipment described in the following paragraphs via the I/O channels of the UYK-7.

1. Link 11

The TDS interface with Link 11 equipment is supported by the Link 11 module, using a single I/O channel and I/O data buffers within the TDS computer.

2. Beacon Video Processor

Control of BVP interrogation and the correlation of BVP reports with tracks is performed by the TDS within the BVP module. This is accomplished using a single I/O channel and alternating input buffers and external function outputs.

3. Radar Video Processor (Experimental; not part of the operational program)

2D radar hit centroids from either the long-range search radar or the surface search radar (not both) are input in real-time to the TDS computer program and processed for clutter correlation by the TDS RVP module. Centroids passing a clutter censor process are transferred to an internal interface buffer for use by the tracking module in updating existing tracks or in the generation of new tracks. The clutter map generated and updated within the RVP module may be displayed on a display console PPI.

4. Pulse Amplifier/Symbol Generator

The Display module within the TDS program, using a single I/O channel, handles communications to and from the display consoles via a Pulse Amplifier/Symbol Generator (PA/SG). Symbols displayed on the consoles are refreshed by continual outputs of the TDS display buffer to the PA/SG. Additional TDS outputs to the PA/SG control the console data readout lamps and pushbutton legends. The PA/SG is also interrogated periodically to detect console operator pushbutton actions.

5. Data Exchange Auxiliary Console

All input and output to the DEAC is controlled by the TDS program DEAC Interface module. These I/O functions handle a dual-drive magnetic tape unit, a teletype printer and keyboard, and a paper tape reader and punch. The DEAC is used for program loading, program reconfiguration, and data extraction.

6. Integrated Circuit Keyset Central Multiplexer

Input and output to the ICKCMX is performed by the TDS program Converter module using a single I/O channel and single word buffers. Data input from the ICKCMX include ship's heading, speed, pitch, roll, underwater battery data, and ESM data.

7. Missile System (Mk 74 Mod 8/WDS Mk 13 Mod 1)

The TDS program interface with the MFCS is supported by the Threat Response module and consists of a single I/O channel to one of the two Mk 152 computers. Targets sent

to the MFCS from the TDS are scheduled by the WDS Mk 13 Mod 1 portion of the MFCS for possible engagement. Schedule information is sent back to TDS for display and operator modification, if necessary. Schedule execution, individual target actions, and engage missile orders are sent to the MFCS by the TDS to conduct radar assignments or other necessary actions.

3.3.5 Tactical Data System Module Functions

Table 3-2 provides brief descriptions and approximate core sizes for the TDS program modules. Not all modules may be resident in the TDS computer at the same time due to core limitations. Manual operations at the DEAC are required to configure the program with the desired program modules.

3.3.6 Missile Fire Control System Computer Program

An identical computer program resides in each of the two Mk 152 (CP-848) computers comprising the Mk 74 Mod 8/WDS Mk 13 Mod 1 MFCS for the DDG-9. Within each program there are two basic modules. These are the Mk 74 Mod 8 module, which drives a director and performs the tracking function, and a WDS Mk 13 Mod 1 module, which contains target scheduling algorithms, casualty display routines, and system operability tests.

3.3.7 Missile Fire Control System Program Architectural Structure

The Mk 152 computer connected to the TDS computer is considered the primary fire control system computer. The WDS scheduling function is performed within that computer. In the other, the secondary computer, operability tests are executed upon operator demand. In normal operation, designation and repeat-back data are passed via an I/O channel from one computer to the other. When a switch is made causing the secondary Mk 152 to become the primary computer, the TDS sends all designation data required to initialize the scheduling algorithms in the "new" primary computer. Scheduling these operations ceases in the secondary computer. Both modules reside within the same computer at the same time; they are arranged sequentially with the Mk 74 module occupying 12k of lower memory, followed by the Mk 13 module.

Within each module are subprograms which are executed to provide the necessary program functions. These subprograms are basically closed subroutines in that they have unique entry and exit points. Since no artificial entry restrictions are imposed, it is possible for one subprogram to call another directly as needed.

TABLE 3-2
DDG-9 TDS MODULE DESCRIPTIONS

Module Name	Brief Description	Core Allocation
Beacon Video	Provides processing required to schedule and control IFF/SIF (selected identification feature) interrogations and provides interface with BVP equipments.	2500
Air/Surface Maneuvering	Supports air control and surface operations of the combat system.	3000
Common Program	Includes common control, systems control, and DEAC interface modules. These modules function to support coordination and control of program operation.	3960
Common System	Contains utility routines and common data stores.	4200
Combat System Alignment Test	Supports alignment testing.	6000
Combat System Interface Test	Supports interface testing.	6000
Combat System Operability Test	Supports operability testing.	6000
Converter	Supports the interface with ICKCMX.	1000
Display	Supports the interface between the TDS program and the display consoles.	6000
Electronic Warfare	Provides an interface between the TDS program and the ship's EW systems.	4000
Link 11	Provides an interface with Link 11 terminal equipment and other TDS program modules.	4000
Navigation	Maintains ownship navigation data and calculates ship position and velocity.	650
Radar Video Processing*	Processes digitized video received from RVP equipments. Assembles and transmits track reports to the Tracking module.	8500
Threat Response	Supports combat system weapon assignment and weapon control functions and provides an interface with the missile systems, the gun system, and the underwater battery system.	8000
Tracking	Supports combat system tracking tasks for both manual and automatic track position entries.	2500

*Experimental

Basic program execution is determined by a small executive program interrupted by the computer clock at 1 ms intervals in order to regulate execution rates and monitor execution overflows.

3.3.8 Missile Fire Control System Executive Program Functions

Due to the sampling nature and other requirements of the radar directing process, the program executive is clock regulated. A basic execution period of 32 ms is divided among three major program functions: Mode and I/O, Radar Control, and Digital System Operability Test (DSOT)/WDS. Each major function is allocated a fixed portion of this 32 ms period, with a maximum of 2 ms allowable for overrun. If a major function exceeds the overrun, its processing is terminated, a computer fault light is lit, and the next major function is initiated. Any processing that is terminated due to time overrun is left incomplete for the rest of the 32 ms time cycle. It is not continued at the termination point in the next time cycle but rather started anew.

The major functions of Mode and Radar Control pertain basically to FCS operations and are allocated approximately half of the 32 ms execution period. Radar direction, tracking, and control I/O is performed in this period. The remaining time is allocated to the DSOT/WDS function. WDS functions are executed if the computer is the primary computer, and DSOT functions are executed if the computer is the secondary computer. Within the WDS function is a secondary execution program that further directs subprogram execution, since not all WDS processing (target scheduling etc.) is performed each WDS period, as are the radar processing functions.

3.3.9 Missile Fire Control System Equipment Interfaces

The fire control system/WDS program communicates with the on-line equipment described in the following paragraphs:

1. Signal Data Converter (Mk 72)

A single digital channel is used for input and output from each Mk 152 computer to an associated Signal Data Converter for communication with a missile radar, a director, the launcher, the Launcher System Module Console (LSMC), and the gun fire control system. Common program routines handle the necessary I/O from different portions of the Mk 152 computer program. Most input is performed within the Mode function, while most output is performed as needed within the Radar Control function.

2. Tactical Data System

Dual-channel intercomputer I/O between the primary Mk 152 and the TDS UYK-7 computer provides for the normal command and control target designation path. Either of the two Mk 152 computers may be switched to the TDS to act as the primary Mk 152.

3. Pulse Amplifier/Symbol Generator

The WDS interface with the PA/SG is performed in TDS casualty situations using the dual I/O channels from the primary Mk 152 that are normally assigned to the TDS. A manual switch operation allows the WDS to drive two display consoles to provide reduced capability combat system operations. In this situation, subprograms within the WDS are called upon to refresh displays and interrogate console inputs, and to respond to operator pushbutton actions. Manual tracking functions are also enabled.

4. Mk 152 Computer

An intercomputer I/O channel is used to link the two Mk 152 computers together for exchange of fire control system repeat-back data and designation data.

3.3.10 Missile Fire Control System Subprogram Functions

Table 3-3 provides brief descriptions and approximate core sizes for the major subprograms of the Mk 152 computers. All subprograms are resident in each of the two Mk 152 computers.

3.4 SOFTWARE DEFINITION, DESIGN, AND IMPLEMENTATION

3.4.1 Tactical Data System Program Definition, Design, and Implementation

The TDS for the DDG was generally defined by NAVSHIPS documents that existed prior to the implementation of the DDG version of the TDS. Such documents included functional requirements, software specifications, hardware and software standards, and certain design diagrams and documents.

At the time the software implementation was under way for the TDS, there was no computer-aided design effort applied to this effort. Since a high-level compiler was not ready for use in 1971, a low-level

TABLE 3-3
DDG-9 MFCS/WDS SUBPROGRAM DESCRIPTIONS

Subprogram Name	Brief Description	Core Allocation
Clock and I/O	Directs program execution and handles I/O.	828
Common Math	Common mathematical routines.	331
Common Constants	Common fixed data storage area.	1048
Common Variables	Common variable data storage area.	1017
Mode	Determines proper radar state - designate, track, etc.	1802
Radar Control	Controls and instructs radar directors.	1255
Angle Tracker	Performs angle tracking functions.	640
SIMUBR	Test simulation.	712
PRR	Decision for Pulse Repetition Rate, selection.	587
Weapons	Handles weapons allocation functions.	1462
Tracking Modifier	Modifies tracking algorithms.	890
Engageability	Determines target engageability.	2648
WDS Tracker	Smooths data for scheduling.	1040
PACILR	Packing routines.	315
NORMGR	Track data update.	62
WDS Data Base	WDS data storage area.	2504
(radar files)*	Radar data storage area.	492
(track files)*	Designation track data files.	857
Reflected Engageability Data	Engageability data.	415
WDS Executive	Directs execution of WDS subprograms.	2061
Queue Verification	Tests targets in queue.	582

*() generic term

Table 3-3 (cont'd)

Subprogram Name	Brief Description	Core Allocation
LS Assignment	Controls launcher system assignment.	143
LSMC/LS Signal Processing	Processes launching system signals.	671
Console Control	Interfaces with PA/SG during TDS casualty.	3436
Display Decisioner	Handles display functions.	517
Schedular Initialization	Initializes WDS scheduler.	121
Recommended Schedule	Contains recommended schedule.	2055
Trial Intercept/ Engagement Display	Performs trial intercept and engagement display.	394
Executed Schedule	Contains schedule to be executed.	1345
Designation Update	Updates designation data.	68

language, ULTRA 32 (later a part of the CMS-2Y assembler), was used to accomplish all the assembly operations. The debug facilities (software program checkout) were located at Mare Island, the land-based test site for approximately 18 months. The programming/checkout involved four to eight persons during the implementation effort. Computer simulation was used to provide the communications Link environment etc. Also, the Junior Participating System was simulated on the CP-642 computer with the Tartar and Link-endaround simulations included. There was no time sharing in the TDS, and the computer software programs were compiled on the machine in the batch mode.

The software architecture was organized in a generally top-down manner with an executive to control the system from the top with program modules designed for each function. Structured programming was not used, and there were no programmer teams involved in the effort. One individual was assigned to each module, and one maintenance programmer was designated to patch the programs during checkout. An open shop was maintained initially where the programmers could exercise "hands-on" operation of the computer during their program checkout. Later a closed shop compiler operation led to better reliability in program implementation and debug.

In order to obtain continuity among different ship systems, the standard algorithms were made available to the software implementers. In this manner the tracking module, utility module, etc. could accomplish the same results regardless of the specific equipment involved. It was noted that the cross-fertilization of library facilities is best enhanced when close communication among the participants is maintained.

One outstanding feature of the software development process was the method of recording program patches. A module was designated and designed for the specific purpose of intercepting patch information when a program was actually being corrected. The program intercepted the patch information, stored it in a data file, and printed it out to be read. This process provided a tremendous aid in keeping track of program changes and the information required to incorporate permanent changes into the program at a later date. Another excellent means of finding and correcting program errors was the generation of Program Trouble Reports (PTR's). These reports were used by those individuals from FCDSSA who were performing the software testing procedures. The PTR's provided a permanent record of trouble areas in the programs and the actions taken to solve the problems.

3.4.2 Fire Control System Program Definition, Design, and Implementation

The functional requirements for the Mk 74 Guided Missile Fire Control System for the DDG were described in Performance Specification

XWS 13917. This document was designed along the guidelines described in WS 8506. An Interface Design Specification (IDS) was developed during the same time frame as Performance Specification XWS 13917.

Because there was no high-level language capability available during the software implementation, the programming was accomplished in TRIM III, an assembly-level language. This assembler was modified somewhat to work on the development agency equipment. The development agency had the computer, radars, signal data converters, etc. available in-house to accomplish their compiling/assembling, debugging, and certain levels of testing.

The implementation effort was organized such that the construction was basically top down in design. Essentially, a design engineer/programmer was assigned to each subprogram. A lead design engineer/programmer was responsible for a program and was also responsible for the integrity of design of his particular program.

3.5 SOFTWARE VALIDATION AND INTEGRATION

3.5.1 Tactical Data System Program Validation and Integration

Three different organizations (Raytheon, Univac, and FCDSSA) participated in the program. The PTR's, described earlier, were used as guides for configuration control instead of the IDS's due to the high-level character of the IDS.

The integration facilities were installed at the land-based test site at Mare Island. There were also facilities for input/output simulation as well as system integration.

The LOGICON ASMD SIM program was used during checkout at FCDSSA(DN) to provide targets. This simulation does an excellent job and requires two CP-642B computers. The Link 11 ALMON (A-Link monitor), using an additional CP-642B computer, was employed to simulate Link 11. The integration testing was under the auspices of OPTEVFOR.

3.5.2 Fire Control System Program Validation and Integration

Each program underwent a series of steps for test and validation. First, the design engineer/programmer wrote his particular program and, operating in an open shop environment, stepped his program through the computer in order to make corrections etc. The program was then presented to the lead engineer for his verification and approval and delivered to the test site (which included the radars etc.) for further testing. The next step in the process was to take the program to Dahlgren

to be run against a Command and Control simulation. After this step, the program went to Mare Island to be processed and tested in the integrated program. After this phase, Naval Ship Weapons Systems Engineering Station (NSWSES) assumed the responsibility for the system performance testing.

3.6 SOFTWARE ACQUISITION MANAGEMENT ORGANIZATION AND METHODS

3.6.1 Tactical Data System Acquisition Management

The organization for the software management functions dealing with the acquisition etc. of the TDS software (Table 3-4) was headed by NAVORD which acted at the Program Office level. NAVSEC was funded for its participation under the Antiship Missile Defense (ASMD) office. The system software contractor was Univac. NSWSES was assigned the responsibility for the performance testing of the complete system (including the FCS).

TABLE 3-4
DDG-9 TDS MANAGEMENT INFORMATION

Program Manager	NAVSEA 6542 (Tartar)
System Contractor	Univac
Type Contract	Cost Plus Fixed Fee
Program Status	Deployed
Maintenance Agent	FCDSSA(DN)
Software Deliverables	Operational Program
Validation Agent	FCDSSA(DN)
Integration Agent	NSWSES

3.6.2 Fire Control System Acquisition Management

The FCS/WDS management information is given in Table 3-5. The Tartar Office within NAVORD controlled the DDG program. The system contractor, Raytheon, was the contractor for the FCS computer software. The organization was set up for Raytheon to report to NSWC who served as the Government laboratory and also was responsible for program maintenance.

TABLE 3-5
DDG-9 FCS/WDS MANAGEMENT INFORMATION

Program Manager	NAVSEA 6542 (Tartar)
System Contractor	Raytheon
Type Contract	Cost Plus Fixed Fee
Program Status	Deployed
Maintenance Agent	NSWC Dahlgren
Software Deliverables	Operational Program
Validation Agent	NSWC Dahlgren
Integration Agent	NSWSES

The management documents for the FCS consisted of Performance Specification XWS 13917, which is discussed above. The interface coordination documents consisted of the IDS, also discussed above.

The software was developed by the system contractor who exercised the internal design audit and review process and also controlled the software configuration with its associated engineering change procedures. Progress measurement and monitoring were accomplished by operational and integration tests performed at Mare Island. Program changes and modifications consisted of PTR's which were sent to FCDSSA(DN) and forwarded to NSWC for implementation.

The weapon system test and evaluation procedures were exercised at Mare Island where the integration of all the components took place. NSWSES assumed the role of systems integration tester and performed those tests. The total system installation at Mare Island provided the testing environment.

3.7 OPERATIONAL SOFTWARE MAINTENANCE

3.7.1 Tactical Data System Operational Software Maintenance

The maintenance facility for the TDS program is FCDSSA(DN). The operational software, after undergoing 16- and 24-hour endurance tests, was transferred to FCDSSA(DN) for implementation and maintenance. Version 0 was accepted on 1 April 1974 and Version 2 has now been accepted. The computer programming language used for this effort was ULTRA 32/CMS-2Y assembler, as discussed previously. There

were no problems involved with the dialects of the language. It was estimated, however, that had the Y compiler been used alone, rather than ULTRA 32 alone, 20% additional code would have been generated. The updating and maintenance functions have been designated to FCDSSA(DN), which controls the procedure for implementing changes into existing Fleet units.

3.7.2 Fire Control System Operational Software Maintenance

It appears that there were no major problems involved in transferring the software to Government control. The program change procedure, as described above, involves first the generation of a PTR which is sent to FCDSSA(DN) and forwarded to NSWC at Dahlgren to be implemented. The operational maintenance responsibility rests ultimately at NSWC to maintain and modify the computer software programs.

3.8 HIGHLIGHTS

The FCS/WDS program was developed in accordance with WS 8506.
(AP2)

The use of general-purpose consoles and computers (commonality of equipment) simplified program design effort. (SE1)

The WDS Mk 13 Program was the first to incorporate an equipment scheduler that provides the FCS coordinator with a recommended engagement schedule. If ordered (by the FCS coordinator) to execute the schedule, the program controls the assignments of fire control radars to targets and the loading and assignment of the GMLS to the fire control systems. (SE1)

For certain ships in the class, the program will provide solutions and control for the simultaneous engagement of an air target with SM-1(MR) and the engagement of a surface target with SSSM(ARM). (SE1)

The TDS program has provision for on-line system reconfiguration. (SE1,SE2,SE3)

The TDS program is modular. (SE1,SE3)

The FCS program has provision for a one-computer reduced capability. (SE2)

Prior to delivery to the ship, extensive system integration testing was conducted at the test facility at Mare Island. (IP3)

For the TDS, there was a single identifiable responsible agent for module design, coding, and implementation. (MS2)

For the TDS, the maintenance agent (FCDSSA) was involved throughout the program design, development, and integration phases. (MS3)

DLGN-38 COMBAT SYSTEM

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4. DLGN-38 COMBAT SYSTEM

4.1 GENERAL SYSTEM DESCRIPTION

DLGN-38 (USS Virginia) is a multipurpose all-digital nuclear-powered guided missile frigate armed with the Standard Missile (SM-1) Medium Range (MR) Weapon System. It is the first of a new class of five ships which are currently authorized. These ships will have missile batteries and lightweight 5"/54 gun systems fore and aft. The fully integrated combat system will utilize a central complex of AN/UYK-7 computers.

The mission of the DLGN-38 class ship is to operate with strike forces and to screen support forces and convoys against submarine, air, and surface threats. Its dominant task is antiair warfare (AAW).

The major data processing subsystems of the DLGN-38 Combat System are the Command and Control System (C&CS), the sensor system (which is integrated with the C&CS), and the missile, gun, and antisubmarine Weapon Systems.

4.1.1 Sensor Interface Data System (SIDS)

The SIDS is a real-time data processing system that provides for the control and correlation of data from the following systems:

1. AN/SPS-48A Radar System

This three-dimensional, electronically stabilized radar provides primary air search and detection capability and moving target indication.

2. AN/SPS-40B Radar System

This two-dimensional radar provides long-range and low-flying target detection, clutter rejection, and moving target indication.

3. Automatic Identification Mk XII System (AIMS)

This integrated AN/UPX-12 interrogator and AN/APX-72 transponder system provides decoded/encoded information for identification.

4. AN/SPS-55 Radar System

This is a surface search radar providing short-range surface detection and navigation.

5. AN/SQS-53A Sonar System

This is a long-range subsurface active and passive search, detection, tracking, and classification system.

6. Electronic Warfare (EW) System

The best available production EW suite, to be defined by OPNAV, will be used initially.

7. AN/SPQ-9 Gun Search Radar System

This radar provides secondary surface detection and navigation capability. It is part of the Mk 86 gun fire control system.

8. AN/URN-20 Tactical Air Navigation (TACAN) System

This system provides relative position information to combat air patrol, surveillance aircraft, or helicopters.

4.1.2 Command and Control System

The C&CS is a real-time digital data processing system that provides command personnel with a summary and control of tactical situations existing throughout ownship and local fleet environments.

4.1.3 Weapon Systems

The following are the major data processing Weapon Systems on-board the DLGN-38:

1. Mk 74 Mod 5 Missile Fire Control System (MFCS)/Weapon Direction System (WDS) Mk 13

This is a digital processing MFCS that provides DLGN-38 with its primary surface-to-air defensive capability.

2. Mk 86 Mod 5 Gun Fire Control System (GFCS)

This is a digital processing GFCS that provides control of the 5"/54 caliber gun during air, surface, and shore engagements and provides the MFCS with a third radar/CW illuminator tracking channel capability.

3. Mk 116 Mod 1 Underwater Fire Control System (UFCS)

Integrated digital processing UFCS element of the anti-submarine warfare (ASW) system.

4.1.4 Supporting Systems

In addition to the preceding data processing systems, the DLGN-38 Combat System also includes the following supporting systems:

1. Launching System

Mk 26 Guided Missile Launching System (GMLS)

Two self-contained automatic launching systems each capable of stowing and handling a mixed load of SM-1(MR) and ASROC.

Mk 32 Mod 7 Torpedo Tube

Two trainable deck-mounted tubes each consisting of three independently operated barrels used to stow and launch Mk 46 Mod 1 torpedoes.

Mk 45 Mod 0 5"/54 Caliber Lightweight Gun Mount

Two shielded, single-barrel, automatic-fire, dual-purpose, lightweight, unmanned gun mounts capable of local or remote control.

2. Communication System

Three digital links (4A, 11, and 14) and a variety of voice communications equipment permitting communications with other elements of an operating task force.

3. Display System

Display of radar data as well as computer-generated information accomplished via the UYA-4 general-purpose display system.

4.1.5 Acquisition History

The DLGN-38 represents the Navy's most advanced digitally automated combat system at the present time. The latest generation computers and displays are used throughout the system.

The DLGN-38 commenced Concept Formulation/Contract Definition in February 1968. The specifications for building Nuclear Guided Missile Frigate DLGN-38, contract drawings, and the Combat System Design Data Document (CSD³) were approved on 21 November 1969. During the same period, the DLGN-38 Ship Acquisition Project Manager (SHAPM) developed plans for the overall ship procurement, financial management, configuration control, procurement of Government-Furnished Equipment/

Each AN/UYK-7 used in a data processing system consists of a cabinet housing seven modules. One of the modules will always be the power supply (P/S). The other modules are the Input/Output Controller (IOC), Input/Output Adapter (IOA), the Central Processor Unit (CPU), and the Memory Units (MU). A maximum of one CPU and one IOC can be housed in each cabinet. Either or both the CPU and the IOC may be replaced by MU's. If the IOC module is replaced by an MU, then the IOA is no longer necessary and will be replaced by a dummy module. If there is no CPU module in a given AN/UYK-7, it is considered an expanded memory frame, rather than a computer. Any unused module slot shall contain a dummy module.

The CPU contains the control circuitry, arithmetic registers, arithmetic timing, and control circuitry necessary to process alphanumeric information. Features of the unit include a repertoire of 130 instructions; a set of privileged instructions for the interrupt state; a nondestructive readout memory; multiple base and index register sets for interrupt and task states; indirect addressing; variable length character addressing; nonassigned instruction trap; and memory read or write lockout or both. It is capable of single precision fixed-point arithmetic, double precision fixed-point add, subtract, compare, test, and double word enter and store, and floating point arithmetic.

The main memory is composed of lithium ferrite core arrays or stacks having a read-restore time of 1.5 μ s. Four stacks, each containing 4,096 32 bit words, are assembled on a chassis to form a 16,384 32 bit word unit. Each unit communicates with the CPU and IOC's over separate memory buses connected to a chassis. Eight interfacing paths (one bus and one port for each path), allowing access to memory, are provided in a 16 word module for communication with other modules. Separate paths are used by the processor for storing and receiving data and for extracting instructions from storage. The interfaces are served in a priority order if simultaneous requests are presented. The order or priority is fixed at the time the interconnecting bus harness is manufactured. An AN/UYK-7 computer complex may contain up to 16 MU's, providing a maximum of 262,144 32 bit words of memory. Optional interleaved addressing between two MU's is possible. This technique requires the designation of each MU to contain only even or odd addresses so that two requesting devices, such as one or more processor or IOC, can make two accesses (retrieve or store) to two blocks of information with each memory cycle. This can result in a reduction in time of as much as 50%.

The IOC controls information transfer to and from peripheral equipment. Signals are transferred through the I/O adapter unit. The IOC uses two types of registers to interface other units of the computer system, the control interface register (CIR), which enables communication with the CPU's, and the data interface register (DIR), used for communicating with memory and an I/O adapter. The IOC contains a repertoire of 15 instructions executable as a part of a CPU-associated command chain or an I/O function associated chain, or both.

The IOA adapts input and output data and controls signal voltages to the voltage requirements of the computer. It contains drivers and receivers for up to 16 I/O channels.

The P/S unit converts primary input power to generate regulated -90 V power which is required by the DC/DC converters contained in each unit. It also furnishes regulated voltages for the maintenance console and operator's panel.

Unused positions in a main cabinet are wired for power and must be filled with a dummy unit if not used by one of the unit types listed above.

The AN/UYK-7 Computer Logic Unit Test Sets are located in the computer room on top of their respective computers. These consoles provide the means of locally controlling the computer for program loading, program debugging, and testing/maintenance purposes.

The AN/UYK-7 Computer Control Units are located in the CIC adjacent to the monitor and control console. The units provide a limited means for remote operator control of computers.

The various features of the AN/UYK-7 data processor, such as memory busing etc., are described in the following paragraphs. With all the capabilities of the AN/UYK-7, there are several interconnection restrictions on communication between computers which greatly influenced the design of the data processing complexes. The CPU, for example, is capable of controlling a maximum of four IOC's. The IOC module, in turn, may be controlled by no more than three CPU's. Other limitations are listed below:

1. A maximum of eight accesses, via memory buses, may be made per MU.
2. A maximum of 16 memory units are addressable by each CPU and each IOC.
3. Each CPU can have two accesses (Instruction and Operand) and each IOC requires one access to memory units via memory buses. A CPU can access a memory unit with either an Instruction or Operand bus only when the system design so dictates.
4. A maximum of 11 memory buses may be routed between adjacent frames.
5. A maximum of five frames may be interconnected.
6. A maximum of eight memory buses may be terminated in any one frame.

4.2.2 Peripheral Characteristics and Selection Criteria

In addition to the computers, the system is supported by the following peripheral equipment:

1. Four I/O Consoles, OJ-172(V)/UYK

The I/O Data Exchange Auxiliary Console (DEAC) provides the data processors of the DLGN-38 Class ships with a collection of I/O devices, grouped into a single cabinet and under a single controller. Each DEAC contains two magnetic tape units, a paper tape reader, a paper tape punch, and a keyboard/printer.

The DEAC is capable of both on-line and off-line operation. On-line operations, performed under computer control, include reading data into the computer and writing data from the computer using the various recording media provided. The read and write functions need not be accomplished with the same recording medium. Teletype communications are also an on-line function. Off-line operations, that is operations performed without computer control, include the using of the paper tape punch or keyboard to write on paper and/or paper tape. The magnetic tape unit and teletype interface unit, capable of only on-line operation, can be operated while the remaining equipment is off-line.

2. RD-281(V)/UYK (Mod) Mass Memory

The RD-281(V)/UYK (Mod) Mass Memory is a disk file providing the function of auxiliary store for the DLGN-38 data processing element. The disk file is capable of reading data stored on the magnetic disk into the computer or writing data from the computer onto the magnetic disk.

3. C&C Signal Data Converter

Two identical C&C Signal Data Converters perform conversion for the various signals aboard the DLGN-38, including D/D, A/D, D/A, synchro-to-digital, and digital-to-synchro.

4. IOC, OA-7984(V)/UYK

This unit interfaces with the C&CS computers. The console contains a keyboard, printer, paper tape reader, and paper tape punch and is used to provide a hard copy of navigation data received via the Navy Navigation Satellite System. In addition, the keyboard will be used to provide navigation inputs to the C&CS computers.

5. Combat System Monitor and Control Group, OJ-200/UYA-4(V).

The console is a Computer Data Terminal (CDT) type device with a CRT display mounted on a duplex/multiplex module. The CDT/CRT display device is capable of operating in either a dark or bright environment and provides a textual display. The duplexer part of the duplex/multiplex module allows two computer I/O channels to communicate with the CDT/CRT display. The multiplexer part provides the capability for up to eight CDT/CRT type devices to communicate with two computers via the multiplexer.

6. Digital Data Switching Group (DDSG), AN/UYA-14

The DDSG contains 32 T-bar relays configured on the DLGN-38 Class ship to provide 16 1×2 switching elements. These elements are used to reconfigure C&C/SIDS, I/O channel interfaces. The switching is controlled manually from either the remote control panel located in CIC or from the local control panel mounted on the DDSG cabinet.

7. Digital Fire Control Switchboard (DFC Swbd).

The DFC switchboard contains T-bar relays in each of its two sections. It is used to reconfigure weapon computer I/O channel interfaces. The switching is controlled manually either from a remote control panel located in CIC or at the switchboard.

8. Universal Data Entry Keyset, MX-3195(V)/USQ-20

This unit is used for entering aircraft data, communications (Link 11) broadcast modes, and navigation data into the C&CS computer. The keyset is located in CIC and will only be used when operators cannot enter data from their consoles because of overloading. The keyset is also used in the casualty mode if the display module controlling the console entries becomes inoperative.

The selection of the above equipment is based upon the following criteria:

1. Standardization of data processing equipment to reduce spare parts logistics and to reduce operation and maintenance complexity (with corresponding reduction in personnel training requirements).
2. Growth potential of the data processing system, permitting the utilization of more advanced technology in other elements of the total combat system.

3. Flexibility of operation required for casualty recovery, on-line and off-line testing, maintenance, and operator training.
4. Simplification of the man/machine interface and the interface between computers and computer-controlled equipment.

4.2.3 Functional Allocation among Computers

The computer system aboard the DLGN-38 is functionally organized into four separate processing complexes:

1. Command and Control System/Sensor Interface Data System
2. Mk 74 Missile Fire Control System
3. Mk 86 Gun Fire Control System
4. Mk 116 Underwater Fire Control System

Utilizing the flexibility of the UYK-7, the DLGN-38 has incorporated both the unit computer concept and the multiprocess/memory-sharing configuration into the design of the combat system. Each of the Mk 74, Mk 86, and Mk 116 systems is supported by a single bay UYK-7 computer (with 1 CPU, 3 MU's, and 1 IOC). Conversely, the C&CS and SIDS systems are supported by a four-bay computer complex. This complex utilizes the multiprocessing capability of the UYK-7. Multiprocessing is performed within the two bays dedicated to the C&CS. The C&CS computers can access the three memory units contained in the SIDS main-frame.

4.2.4 Interrelation among Computers and Sensor/Weapon Interfaces

The use of general-purpose machines, redundant equipment, and multiple data flowpaths permits the retention of operational readiness even under a high level of casualty. Therefore, the system is designed to recover from casualties ranging from the loss of a single peripheral device to the loss of a whole bay. The number of reconfiguration alternatives is too great to address in this appendix. For more information on casualty reconfiguration, it is suggested the reader refer to Section C of the DLGN-38 Integrated Combat System Design Data Document, NAVSHIPS 0967-014-1040.

4.3 COMPUTER PROGRAM ARCHITECTURE

The following sections discuss the software architecture for the DLGN-38 Combat System. A discussion is given for the C&CS/SIDS computer complex, and the Mk 74 MFCS has been selected as an example of the many Weapon System programs.

4.3.1 Command and Control System/Sensor Interface Data System Computer Programs

The DLGN-38 C&CS/SIDS computer programs are designed to operate in a four-bay AN/UYK-7 complex consisting of 13 memory units (212,992 words). The modular configuration for both the C&CS and SIDS programs may be loaded by the Monitor Control Console (MCC) Operator at the OJ-200 console. The operator selects from a predetermined list of configurations, each of which are based on a required level of readiness. In the event that a modular configuration is currently loaded and additional capabilities are desired, the operator, via Dynamic System Reconfiguration (DSR), can select individual modules which provide the required capability to be loaded from the RD-281 disk memory, or the OJ-172 as a backup.

4.3.2 C&CS/SIDS Program Architectural Structure

Both the C&CS and SIDS programs are divided into a series of identifiable subprograms called "modules." These modules are grouped in a variety of configurations to satisfy the various levels of readiness conditions of the DLGN-38. Each module falls into one of the four categories listed below:

1. Resident Control module — requires full-time residency in core (e.g., Executive).
2. Base module — provides required support function in all configurations (e.g., Display).
3. Configuration Alternative module — provides warfare and operational capability to support mission requirements (e.g., Threat Evaluation).
4. Transient module — provides selected capability that can be utilized and then deleted or replaced with another capability as needed (e.g., Training).

A configuration selected for a condition of readiness will consist of all Resident Control and Base modules and the selection of appropriate Configuration Alternative modules. Transient modules will be loaded separately when required.

4.3.3 C&CS/SIDS Executive Programs

Both the C&CS and SIDS programs use the Common Program Executive designed by Univac. This executive can operate in a multiprocessor mode (C&CS) or can be adapted to a single processor (SIDS).

4.3.4 C&CS/SIDS Equipment Interfaces and Module Functions

Communication with other systems is accomplished through a series of interface modules. Each of these modules is designed to send and receive data from another system in a form that is acceptable to that system.

Table 4-2 gives a brief description of each module in the C&CS program with the projected (resident plus nonresident) core requirements of each module. Table 4-3 gives a brief description of each module in the SIDS program with representative core requirements of each.

4.3.5 Mk 74 Mod 5/WDS Mk 13 Mod 0 -- Missile Fire Control System Computer Program

The MFCS program resides in a single UYK-7 computer and performs two basic functions: FCS radar control and WDS target scheduling. Both functions are performed on an almost independent basis as two computer programs.

4.3.6 Missile Fire Control System Program Architectural Structure

Of the two basic functions, FCS radar control and WDS target scheduling, the radar control is the more time critical. Consequently, the radar control program is executed in the Executive state of the UYK-7, while the WDS program is executed in a "background" sense in the Task state of the computer during unused FCS time.

Each program is controlled by its own Executive, with a clock-interrupt scheme to monitor and control the FCS Executive program. Each Executive calls upon subprograms, or modules, to perform desired functions, and all I/O is performed by common routines in the Executive state of the computer.

The overall program is modular in the sense that series of closed routines, called subprograms, are grouped together in modules to perform basic identifiable functions. Six modules contain 29 subprograms.

4.3.7 Missile Fire Control System Executive Program

Processing of tasks within the radar control program is regulated by a clock-interrupt-driven Executive program. All required FCS functions are performed within each repeated 32 ms time frame, with all unused time provided for Task state execution of WDS functions. All WDS processing is performed within a 2 second period.

TABLE 4-2
C&CS PROGRAM MODULE DESCRIPTIONS

Module/ Segment Group	Module (segment) Name	Brief Description	Core Alloca- tion
Resident Control	Common Control	Executive for C&CS program.	4,280
	Common Peripheral	Permits communication with OJ-172 paper tape, magnetic tape units, teletype, etc.	5,406
	Common System	Regional and global data base for C&CS track data, weapon data and status, etc.	15,390
	Dynamic Reconfiguration	Provides for reconfiguration of the on-line program.	5,437
	System Control	Supports use of MCC for controlling system configuration and provides for monitoring of overall combat system performance — provides alerts.	18,170
	System Loader	Loads the program in core from tape or disk.	91
	Debug	Provides for computer program problem resolution.	11,300
Base	Display	Provides for OJ-194 console PPI symbology, lines, etc., data read-outs (remote and attached to console). Interrogates consoles and passes data to responsible modules.	19,863
	Tracking	Provides for manual tracking, correlation of C&CS tracks with EW data, fire control system data, and remote Link 11 tracks with local tracks.	11,916
	Identification	Provides for assignment of an ID (friend, hostile, etc), category (air, surface, subsurface), and classification (cruiser, fast patrol boat, etc.).	2,765
	Signal Data Converter	Interrogates Signal Data Converter Mk 72 to obtain ship parameter data (course, speed, roll, pitch), logical status from external systems, etc.	3,389

TABLE 4-2 (Cont'd)

Module/ Segment Group	Module (segment) Name	Brief Description	Core Alloca- tion
Base (Cont'd)	Navigation	Provides for entry of ship position and accommodates (dead reckoning) motion of ship geographically between fixes.	8,850
	Link 11	The intership data link that passes track data, weapon status, force orders, etc. Also used between ships and P-3 aircraft.	14,313
	Surface Operations (surface maneuvering)	Provides for calculations of point-to-point ship maneuvers, collision avoidance alerts, closest point of approach calculations, etc.	11,044
4-14 Configu- ration Alterna- tive	Gun Interface	Provides interface with Mk 86 gun fire control system.	4,296
	Missile Interface	Provides interface with Mk 74 MFCS and WDS Mk 13.	5,608
	ASW Interface	Provides interface with Mk 116 Mod 1 UFCS	6,226
	SIDS Interface	Provides interface with sensor interface data system via shared memory — supports BVP and RVP operator modes.	10,576
	Threat Evaluation	Provides a relative threat ranking of system tracks, both air and surface, to facilitate correct order of engagement.	2,611
	Weapon Assignment	Provides for response to force or locally ordered engagements, selects targets in order of engagement priority and weapon availability.	12,778
	Height — Size	Provides for interface with SPS-48 Radar Set Control (RSC), allows entry of track height, depth, and size either at the RSC (height only) or via entries at console modes.	1,941
	ASW Management	Provides for operator controls and displays at the ASW console mode and surface/subsurface surveillance coordinators mode to control sonar search, classify contracts, etc. Convergence Zone Calculation.	5,669

TABLE 4-2 (Cont'd)

Module/ Segment Group	Module (segment) Name	Brief Description	Core Alloca- tion
Configu- ration Alterna- tive (Cont'd)	Sonar Processing	Provides for direct input of SQS-53A sonar data into C&CS when the Mk 116 UFCS is off-line. Tracks sonar targets and presents displays for use in urgent attack using over the side torpedoes.	3,616
	Air Control (in- tercept vectoring)	Provides for calculation of intercept geometries and all actions associated with the control of interceptor, ASW fixed-wing and helicopter aircraft. Support of LAMPS Mk 1 is in ASW management module (sonobuoy management).	10,064
Transient	Link 4A	Provides for interconnection of the air control function with Link 4A orders, status, and responses.	9,022
	ASW Management (sonobuoy manage- ment)	Provides support for LAMPS Mk 1/fixed-wing ASW sonobuoy data, computation of hyperbolic and comparative LOFAR fixes.	886
	Link 14	Provides for a one-way teletype link to broadcast track and engagement data to non-TDS ships; only one ship per force broadcasts.	3,781
	Satellite Naviga- tion	Provides for calculation of ship position using SRB-9 satellite data.	7,579
	Electronic Warfare	Provides only a basic capability for manual entry of EW data, bearing lines, and EW fixes.	3,309
	Test Control	Provides for system testing using combat system operabil- ity, alignment, and interface tests. Provides capability to call in Programmed Operational and Functional Appraisal (POFA) programs to test suspected equipment faults while the Operational Program is still on-line.	9,826
	Training	Provides for control of SM-441 video simulator, which pro- vides targets for local training and passes targets to other ships via Link 11 for force training.	7,625

TABLE 4-2 (Cont'd)

Module/ Segment Group	Module (segment) Name	Brief Description	Core Alloca- tion
Transient (Cont'd)	Data Extraction	Provides a capability to extract a continuous summary of events, buffer traffic between systems link data, etc. for later reduction and analysis.	5,925
	DX Control	Provides control over data extraction (DX) process (Tactical and Continuous System Operational Test).	20,105

TABLE 4-3
SIDS PROGRAM MODULE DESCRIPTION

Module Group	Module Name	Brief Description	Core Allocation
Resident Control	Command Control Common System System Loader Debug	See Table 4-2.	3,600 8,124 4,507 5,114
Base	C&CS Interface	Provides interfaces with C&CS via shared memory	564
	Sensor Data Management	Provides for the control and coordination of data received from on-board sensor.	11,226
	Beacon Video Processor	Provides for the operation and control of the BVP	5,523
	Radar Video Processor	Provides for the operation and control of the RVP	8,525
Transient	Common Peripheral	See Table 4-2	5,278
	Data Extraction		7,444
	DX Control		1,613

4.3.8 Missile Fire Control System Equipment Interfaces

I/O functions are called upon as needed, using common routines, to interface with the Naval Tactical Data System (NTDS), Signal Data Converters, the gun fire control computer, displays, two Mk 26 launchers, and two launching system consoles.

1. NTDS Interface

NTDS target designations, engagement orders, and scheduling data are exchanged using a single I/O channel from a C&CS computer to the MFCS computer (MFCC).

2. Signal Data Converter

Two Signal Data Converters are used to exchange director and radar feedback and commands with the MFCC. One Signal Data Converter and MFCC channel are used for each director.

3. Launching System Module Console (LSMC)

Two LSMC's are interfaced with the MFCC using a single I/O channel to display launcher status and to transfer LSMC orders to the MFCC.

4. Gun Fire Control Computer (GFCC)

An intercomputer I/O channel is used to exchange data between the missile system and the gun system. This allows the use of the gun director for missiles and inter-director designations between the gun and missile systems.

5. Pulse Amplifier/Symbol Generator (PA/SG)

A single MFCC I/O channel is provided to drive UYA-4 console displays and to allow manual inputs for NTDS casualty operation. This channel may be switch-selectable as an input to the PA/SG.

6. Mk 26 Launcher

The MFCC interfaces directly with each of the two Mk 26 missile launchers, using one I/O channel each, to exchange launcher orders and repeat-back data.

4.3.9 Missile Fire Control System Module Functions

The primary functions of the MFCS modules and their approximate core allocations are given in Table 4-4.

4.4 SOFTWARE DEFINITION, DESIGN, AND IMPLEMENTATION

The DLGN-38 commenced Concept Formulation/Contract Definition in February 1968. During this process detailed studies and designs were carried out, leading to the completion of ship contract specifications and drawings, and the guidance document describing the combat system baseline design. The specifications for building Nuclear Guided Missile Frigate DLGN-38 and contract drawings and the Combat System Design Data Document (CSD³) were approved on 21 November 1969.

TABLE 4-4
MISSILE FIRE CONTROL SYSTEM MODULE FUNCTIONS

Module	Brief Description	Core Allocation
Executive	Contains initialization, interrupt controller, Task controller, and I/O.	4,760
FCS	Determines radar modes, frequency selection, weapons orders, and tracking.	8,690
WDS Communication	Controls launcher and C&CS communication. Controls consoles in casualty.	6,685
WDS Scheduling	Determines target engageability, target scheduling, launching system assignment, designation update.	7,887
Operability	Performs system monitoring and Daily System Operability Tests.	4,012
Common	Contains common subroutines.	1,085

The program production phase consists of the determination of requirements, the development of program specifications, and the production of the computer programs. This first step takes place at the vendor or program maintenance agency plant and terminates when the programs are validated and delivered to the Shore Systems Integration Site (SSIS) for combat system integration testing.

The following baselines were established to serve as technical references for the design and implementation stages.

1. Functional Baseline

The Functional Baseline was established through definitions and descriptions of the following system documents:

- a. NTDS Tactical Operational Requirements for DLGN-38.
- b. DLGN-38 Integrated Combat System Design Data Document, NAVSHIPS 0967-014-1040.
- c. Interface Design Specifications.

2. Allocated Baseline

The Combat System Allocated Baseline was established when the Navy accepted the Computer Program Performance Specifications for each subsystem.

3. Product Baseline

The Combat System Product Baseline is defined by the Navy-approved Program Design Specification, Test Plans and Procedures, Operating Procedures/manuals, and tapes and listings. The Product Baseline will provide the information necessary for procurement, integration, and acceptance of combat system computer programs for subsequent ships of the DLGN-38 Class.

4.5 SOFTWARE VALIDATION AND INTEGRATION

Each subsystem computer program is subjected to checks at various shore-based test sites until final acceptance testing is conducted on board the ship. The objective is to produce a mission-capable ship and to demonstrate this capability during final contract trials (FCT).

The initial integration phase includes all activities at the SSIS wherein the programs, upon receipt, are placed under formal configuration control. These programs undergo integration and testing employing the SSIS facility. This step will terminate with the completion of integration and the transfer of the programs from the SSIS to the ship/Fleet Combat Direction System Support Activity (FCDSSA), Dam Neck (DN).

The next stage of the overall program development includes shipboard testing up to and including the Operational Program Functional Checkout (OPFCO). During this time, the programs will be undergoing a continuing series of tests at both the maintenance facilities and on board the ship. Prior to introduction to the ship, the C&CS/SIDS programs will undergo preliminary acceptance testing at FCDSSA(DN). Other subsystem programs will undergo preliminary acceptance tests at SSIS and other support centers. This phase is terminated by the formal acceptance of the program following OPFCO.

4.6 SOFTWARE ACQUISITION MANAGEMENT ORGANIZATION AND METHODS

The complexity of the DLGN-38 Class combat system with its several component computer programs dictates the establishment of a vigorous management scheme. Overall responsibility for the procurement, design, and integration of the DLGN-38 combat system is vested in the

AAW Ship Acquisition Project Manager (SHAPM, PMS-378). During the period February 1968 to November 1969, SHAPM developed plans for the overall ship procurement, financial management, configuration control, procurement of Government-Furnished Equipment/Government-Furnished Information, and other items as set forth in the Ship Acquisition Plan.

The Product Baseline, as described in Section 4.4, will be used in the acquisition of combat system software for subsequent ships of the DLGN-38 Class.

SHAPM has established a management organization that permits the orderly procurement and integration of all elements of the combat system. Table 4-5 indicates the various organizations assigned to meet this goal.

TABLE 4-5
SOFTWARE MANAGEMENT INFORMATION, DLGN-38 CLASS

	C&CS/SIDS	Mk 116 UFCS	Mk 74 MFCS	Mk 86 GFCS
Program Manager	NAVSEC	NAVSEA	NAVSEA	NAVSEA
System Contractor	Univac	NUC	Raytheon	Lockheed
Type Contract	CPFF	WR	FP & LOE	LOE
Program Status	Ship Testing	Ship Testing	Ship Testing	Ship Testing
Maintenance Agent	FCDSSA(DN)	NUC	NSWC Dahlgren	NSWC Dahlgren
Software Deliverables	Operational Program and Program Documentation			
Validation Agent	NAVSEC	NAVSEA	NAVSEA*	NAVSEA
Integration Agent	Combat System Integration Manager			

*FCDSSA(DN) assigned as SHAPM agent to witness and report to SHAPM on program certification

CPFF = Cost plus fixed fee

WR = Work request

FP = Fixed price

LOE = Level of effort

4.6.1 Management Plan

The Integrated Combat System Management Plan (ICSMP) for the DLGN-38 Class is derived from the DLGN-38 Ship Acquisition Plan and from the chartered responsibility for acquisition of the ship by the SHAPM. The ICSMP provides for management of combat system integration by establishing and coordinating the schedules, work plans, facility requirements, etc. of agencies participating in development.

The document is the parent document for all the supporting Combat System Management efforts required. The tasks of this document which relate to tests provide the guidance for the overall Combat System Test Plan (CSTP) which has as its end purpose the demonstration that the combat system meets all requirements. The CSTP was contractually invoked with the shipbuilder by Headquarters Modification Requisition (HMR-144) forwarded by NAVSEA ltr PMS378/JJD Ser 1195 dated 4 November 1974.

Because of the many tasks involved, the details of the tasks are developed in the ICSMP, showing an agency's responsibilities and contributing activities. By this means each agency can determine the impact of its assignment on other tasks being performed. The level of tasks identified in the ICSMP is only as deep as major assignments to individual agencies. Ship Project Directives written to accomplish these major task assignments are in greater detail and consist of line items against which funds will be allocated.

4.6.2 Software Configuration Management

The development of the DLGN-38 computer programs is divided into three major phases:

- Phase I - Program Production and Initial Integration
- Phase II - Program Integration and Shipboard Delivery
- Phase III - Program Maintenance

The management and control of configuration is facilitated through the establishment of baselines. These baselines serve as technical references from which the system elements may evolve to eventually become operational systems. Since MIL-STD-480 and NAVMATINST 4130.1A do not detail the configuration control of computer programs to the degree necessary for DLGN-38 Class combat systems, the Software Configuration Control Procedures manual, NAVSEA 0900-LP-080-2010, expands basic terms and adds new terms where necessary. The four baselines are the Functional Baseline, the Allocated Baseline, the Product Baseline, and the Operational Baseline.

The primary control over software is vested in the Software Configuration Control Board under the direction of FCDSSA(DN). This board exercises its control through a series of reviews and audits as discussed below:

1. Preliminary Design Review (PDR). The conduct of program documentation reviews is the responsibility of the Navy manager tasked with the individual program development. The PDR serves as a means for reaching common agreement between the Navy and the development contractor on the content of deliverable documentation as specified in the Critical Design Review (CDR). Acceptance of/or corrections to the documentation will be determined during the PDR. PDR's are scheduled by the Subsystem Managers as required to ensure prompt processing of action items and to comply with formally established design review milestones.
2. Critical Design Review. The CDR includes a comprehensive review of the individual system to include system configuration, design details, and tests considered critical to ensure satisfactory compliance with performance requirements. The CDR is conducted on an incremental basis rather than as a single CDR, to provide progressive reviews to disperse the load over an extended period of time; however, a final CDR is scheduled to provide a last overview and clearer insight into program technical risks associated with each Configuration Item. The risk discussions are addressed on a cost and schedule basis in addition to the technical problems involved.
3. Configuration Inspections/Audits. Prior to beginning certification testing, a team designated by SHAPM for the purpose of conducting configuration inspections shall be formed. This team shall be authorized to visit the development activity/maintenance activity of each Subsystem Manager to establish the pre-preliminary Product Baseline of each system that will undergo independent formal validation testing prior to Phase I integration at SSIS. This inspection will determine the following data for use in describing the baseline system:
 - a. Documentation status.
 - b. Current status of programs and tentative schedule for validation testing.
 - c. Configuration control procedures currently in use at the particular activity.

- d. Degree of Navy control of current Contract Data Requirements List items (i.e., accepted deliverables, under or not under configuration control).
 - e. Activity responsible for documentation/software maintenance (if contractor).
4. Preliminary Product Baseline Configuration Audit. Upon completion of validation testing of each subsystem, the Preliminary Product Baseline configuration audit shall be validated to ensure that the developed programs performed as specified and that documents have essentially been completed. At this time the documentation and software configuration items comprising the Preliminary Product Baseline will be placed under formal configuration control and the directives of the Configuration Control Procedures Manual will be instituted for all subsequent actions affecting both documentation and program changes.
5. Final Software Audits. The final audit of computer programs and their associated documents will be performed just prior to the final delivery of updated programs and documents by all activities to FCDSSA(DN). This audit shall be made after successful completion of the Operational Performance Functional Checkout (OPFCO) and shall result in establishment of the Operational Baseline. This audit will assure that the configuration listing for all programs is correct and up-to-date upon commencement of the program life cycle maintenance phase. All program master tapes, noncompiled patches, and verified copies of all required documentation will be deposited at FCDSSA(DN) where configurations will be rigorously controlled and reports of status issued on a periodic basis. Procedures for acquisition of tapes are set forth in the Configuration Control Procedures Manual, Section 4.

4.6.2.1 Audit Guidelines

The following general provisions are applied to audits:

- 1. Audits shall be kept to the minimum number necessary to provide acceptable visibility.
- 2. Demonstration requirements, including where, when, and the scope/degree of the audit, will be specified in detail at the time of scheduling.
- 3. Prior to establishment of the Operational Baseline, the responsibility for scheduling audits will reside with the Combat System Manager.

4. After the operational baseline is established and the life cycle maintenance phase is instituted, the Commanding Officer FCDSSA(DN) will be responsible for scheduling audits in compliance with the assigned task of continued DLGN-38 combat system computer program configuration control.
5. Audits will be scheduled to allow the activity subject to audit 30 calendar days in which to prepare for the formally stated audit requirements.

4.7 OPERATIONAL SOFTWARE MAINTENANCE

Phase III of the DLGN-38 combat system is initiated by the successful completion of OPFCO. It is during this period that the ship, with its combat system, is turned over to the Operational Fleet Commander. This marks the beginning of the life-cycle maintenance phase as opposed to the life-cycle production phase. Configuration control by SHAPM continues until Final Contract Trials some eight months after OPFCO at the termination of Ship Construction Navy (SCN) funding.

The Operational Baseline is a useful configuration control device for this phase. NAVMATINST 4130.1A, paragraph 1-5.g, states, "Baselines will be established at those points in a program where it is necessary to define a formal departure point for control of future changes in performance, design, production and related technical requirement" (Emphasis added).

Due to the radical shift in responsibility, funding, and accounting for software in shipboard combat systems when the production phase ends and the ship becomes operational, an extension of the Product Baseline under the name of Operational Baseline is established. The combat system Operational Baseline will be established upon completion of OPFCO and Navy acceptance of all shipboard integrated subsystem programs with associated hardware items. This baseline shall provide for the development and shipyard testing of subsequent ships of the class as a Product Baseline. The distinction is necessary for maintenance accountability.

Post-Delivery Software Audits are another important technique for handling operational software maintenance. During the life-cycle maintenance of computer programs, revisions to documentation and software will be required. The changes result from:

1. Navy at-sea tests,
2. Fleet-generated Program Change Proposals (PCP's) or Trouble Reports (TR's),

3. Field changes to improve or meet changing tactical requirements, and
4. Engineering Change Proposals (ECP's).

It is therefore necessary to periodically re-audit the programs and documentation to assure conformity to the revised technical configuration identification documents. Post-delivery audits will be performed by FCDSSA(DN) in conjunction with the NAVSEA-assigned program maintenance activity as necessary to assure complete life-cycle visibility and control of the total combat system software.

4.8 HIGHLIGHTS

DLGN-38 development requirements were primarily derived from those of the immediately preceding frigate class (which was itself still in development). (MP1)

The DLGN-38 Command and Control System (C&CS) has significantly overrun allocated computer resources. This can be attributed to changing and growing requirements during system development and errors in contractor estimates of module size. (MP1,SE2)

Rigorous controls over program development are ensured by a well-defined and concise Management Plan (which is strictly followed). This plan includes:

1. Specific statement of objectives and
2. Identification of tasks, responsible person or agency, dates, and deliverable items. (AP1)

The Integrated Combat System Management Plan (ICSMP) is derived from the DLGN-38 Ship Acquisition Plan. The ICSMP provides for management of combat system integration by establishing and coordinating the schedules, work plans, and facility requirements of agencies participating in development. The tasks of this document provide guidance for the overall Combat System Test Plan (CSTP). (AP1)

The DLGN-38 Sensor Interface Data System (SIDS) is the first Navy attempt at an automated integrated sensor system. The SIDS/C&CS computer complex is also a pioneering example of separate software system developments within a shared-memory and multiprocessing architecture. (SE1)

Standards in force at the time of Contract Definition were applied to the selection of computer type, peripheral and switching equipment, consoles, language, and documentation. This facilitated the procurement, development, and integration processes. (SE1)

Software control is vested in the Software Configuration Control Board under the direction of the Fleet Combat Direction Systems Support Activity (FCDSSA(DN)). This board exercises control through a series of reviews and audits. Its establishment has resulted in a single agency (FCDSSA) being assigned the responsibility for implementation of design audits, Interface Design Specifications (IDS), and software Engineering Change Proposals (ECP). SHAPM has secured permission from OPNAV for FCDSSA to report directly to SHAPM for this function.

(SE1,MS3)

Early design freeze followed by program certification prior to delivery provides stable program development control.

(SE3)

Extensive verification activity has been carried out at the Mare Island Test Site to determine that the Interface Design Specifications (IDS) had been correctly implemented. A separate facility is being assembled at FCDSSA(DN) for operational support and operator training. Simulation programs for subprogram development were funded as a recognized element of the program.

(IP1,MS3)

Continuing individual responsibility follows through both industrial and Navy testing, thus assuring continuity of program validation.

(MS1,MS2,MS3)

Management and configuration control is facilitated by establishing baselines. These baselines serve as technical references from which the system elements will evolve to become operational systems. Since MIL-STD-480 and NAVMATINST 4130.1A do not detail the configuration control of computer programs to the degree necessary for DLGN-38 Class combat systems, the Software Configuration Control Procedures Manual expands basic terms and adds new terms where necessary.

(AM2)

5. AIRCRAFT CARRIER (CV) TACTICAL DATA SYSTEM

5.1 GENERAL SYSTEM DESCRIPTION

The carrier forces planned for the U.S. Navy will consist of 12 ships divided into two Fleets, the Atlantic and the Pacific. Four of the 12 carriers are or will be nuclear powered, giving them the advantage of being able to make long transits and remain on station for extended periods without refueling main-ship propulsion.

Aircraft carriers can be assigned strike, support, or antisubmarine warfare (ASW) missions, or any combination. Their primary mission is to support embarked operational aircraft, to attack targets that threaten control of the task force, and to support sustained operations of other forces as assigned. The fighter-interceptor complement of the carrier air wing provides Fleet long-range task group air defense capability. Effective adjuncts of the carriers' sensor systems are embarked airborne early warning (AEW) aircraft with their HF data link capability. A vital element of fighter defense is the additional UHF data link between the ship, AEW aircraft, and interceptor aircraft.

Every carrier has two operational centers that deal with the command and control of aircraft: the Combat Information Center (CIC) and the Carrier Air Traffic Control Center (CATCC). Each has its own supporting sensors. The CIC is concerned with the management of weapons for defense; the Naval Tactical Data System (NTDS) is an essential part of its operational support. The CATCC is concerned with the safety of embarked aircraft. The CIC and CATCC aboard the modern carrier are automated for high-capacity aircraft control.

The main system elements include sensors, Combat Direction/Weapon Direction Systems (CDS/WDS), missile systems, Air-Traffic Control (ATC) systems, electronic support measures (ESM) and electronic warfare (EW) equipment, and voice and digital communication link equipment. The sensors and the missile systems differ among the CV's since independent configuration update programs are constantly in progress.

5.1.1 Sensors

Search radars and associated identification friend or foe (IFF) systems provide the capability for detection and identification of air and surface targets within horizon ranges. The typical search radars consist of the medium-range surface search radar AN/SPS-10, the three-coordinate long-range air search radar AN/SPS-48, and the two coordinate long-range air search radar AN/SPS-43. Several carriers have SPS-39 or

SPS-30 radars instead of the SPS-48, and the SPS-12 and SPS-37 radars instead of the SPS-43. IFF capability is provided by the Automatic Identification Mk XII System (AIMS) (or Mk X). Air-traffic control is provided by the AN/SPN-43 radar, a two-coordinate ATC unit.

IFF video processing equipment, namely the Beacon Video Processor (BVP), operates upon analog IFF data to provide digital automatic identification and positioning of friendly aircraft suitably equipped. The BVP contains a general-purpose digital computer, CP-789/UYK. A video processor designated the Signal Data Converter operates on the AN/SPS-43 and SPS-12 video to provide digitized video and azimuth information, but it is being replaced with a variety of digitizers.

5.1.2 Combat Direction System

The combat direction operations are handled through NTDS. NTDS provides data entry and display, automatic data processing, communication link control, and Weapon System designation control. NTDS equipment includes four general-purpose digital computers (CP-642/USQ), 256k of extended memory, 20 to 24 operator data entry and display consoles (AN/SYA-1, SYA-4, UYA-1, or UYA-4), a variety of data conversion and designation equipment, and various peripheral devices including digital data link units and analog converters.

5.1.3 Weapon Direction System

The WDS Mk 5 Mod 2 is interfaced with the NTDS and provides coordination and control of the missile Weapons Systems.

Most CV's have either the Terrier guided missile system or the Basic Point Defense (BPD) system. CV-63 (and possibly others) have the NATO Sea Sparrow Missile System (NSSMS).

The Terrier ships use three guided missile fire control systems (GMFCS) Mk 76 Mod 3; the BPD ships use either two or three GMFCS's Mk 115 Mod 0.

5.1.4 Carrier Air-Traffic Control System

The ATC function is integrated with the NTDS and is designated collectively as Carrier Air-Traffic Control (CATC). The functions of marshalling and departure are handled through four operator consoles of the NTDS. Sensors and tracking systems associated with CATC approach are the two-coordinate ATC radar AN/SPN-43 and the landing control system AN/SPN-42. The AN/SPN-42 includes two guidance (tracking) radars and two general-purpose digital computers (Univac 1219).

5.1.5 Electronic Support Measures and Electronic Warfare Equipment

ESM equipment consists of an electronic countermeasures (ECM) receiving set, the AN/WLR-1 and, on several CV's, the AN/SLR-13. EW equipment consists of countermeasures set AN/ULQ-6, which is interfaced with the NTDS.

5.1.6 Communication Links

The communication links interfaced with the NTDS are Link 11 (computer-to-computer with other NTDS ships), Link 4A (digital control information to aircraft), and Link 14 (NTDS station to non-NTDS station).

5.1.7 Acquisition History

The Fleet Combat Direction System Support Activity (FCDSSA) at San Diego (SD) has the responsibility for developing and maintaining NTDS software for this class of ship. FCDSSA(SD) designed and implemented the NTDS program for the CV, CG, DLG-28 Class, and LCC. The development of the NTDS program for the CV used previously developed FCDSSA NTDS programs as a baseline design.

Each CV Operational Program is designated by a model and phase number. A model change involves a change in intership Link 11 message formats. A program may also be restructured when a model change is required. A phase change typically occurs every 2 years. It incorporates into the program library all minor changes that have accumulated in that time and that have been patched or deferred.

The NTDS program for the CV was developed at FCDSSA using in-house personnel to generate the Functional Operational Design and level-of-effort contracting to generate the program design and code for each user module. The contractor worked at the FCDSSA facility which provided the necessary equipment and support software. All software design at FCDSSA(SD) is done by in-house personnel, and Navy software is used as the basis for all program development.

Prior to 1973 there were attack carriers (CVA's) and ASW carriers (CVS's). The difference in the tempo of operations made it impractical to mix the attack and ASW missions. Moreover, the ASW mission was not supported by the NTDS. With the introduction of the S-3 Viking aircraft, it was decided that any carrier should conduct any mission. Therefore, in 1975, carriers are deploying with both attack and ASW aircraft aboard.

In 1974, the first F-14 squadron deployed on carriers. The data link associated with this aircraft required a small change in NTDS UHF link software to use feed-back data from the aircraft.

5.1.8 System Diagram

A system block diagram for a representative carrier tactical data system is shown in Fig. 5-1. Functional relationships among the primary system elements are indicated on the figure.

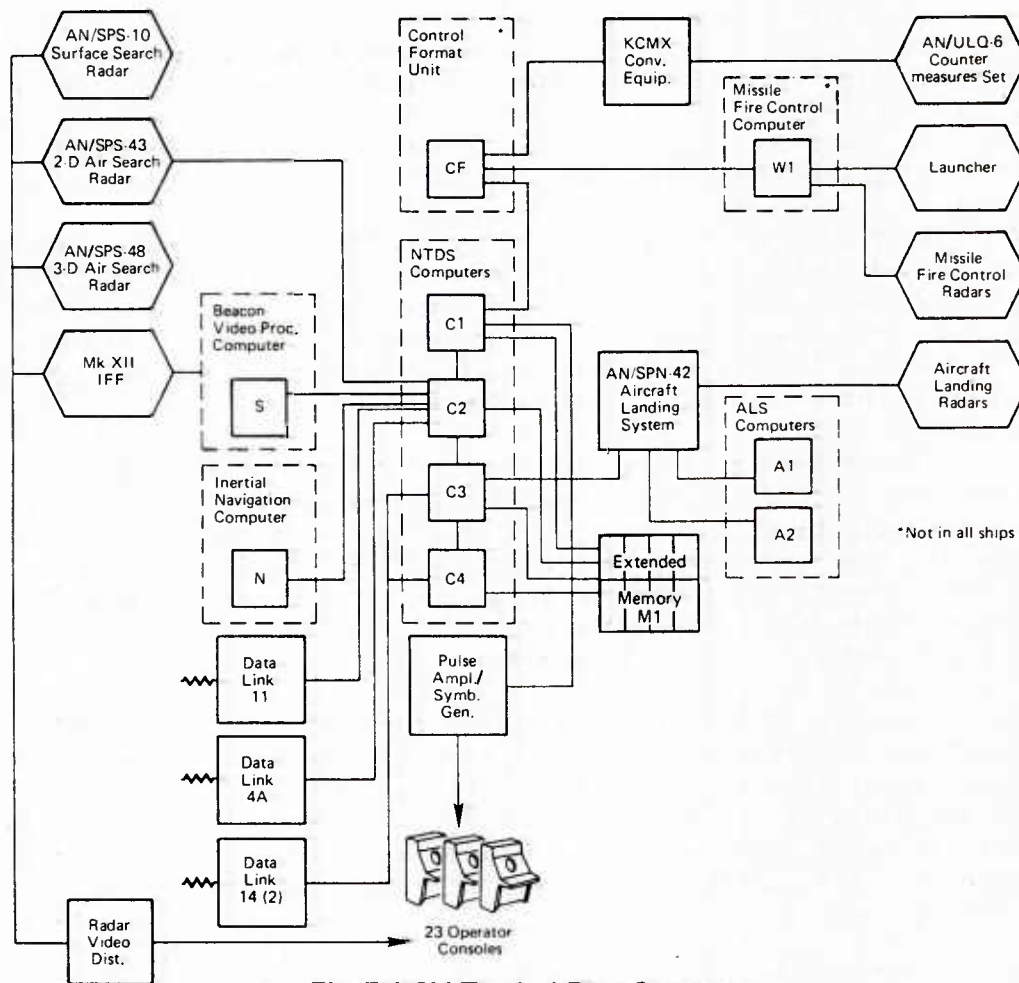


Fig. 5-1 CV Tactical Data System

5.2 COMPUTER SYSTEM ARCHITECTURE

5.2.1 Computer Characteristics

Carrier tactical data systems with either the Terrier missile or the BPD system include either eight or nine general-purpose digital computers. The ninth computer is the Control Format Unit (CFU) which is not installed on all CV's. Carriers with the NSSMS include the CFU and a tenth digital computer, fire control Mk 157. Table 5-1 presents a summary of these computers. The unit designation (S, N, C1, etc.) is keyed to the system diagram, Fig. 5-1.

Table 5-1
CV COMPUTER SUMMARY

Unit	Type	Function	Pro- cessor	Memory
S	CP-789/UYK (18 bit, 4 μ s)	Beacon video processing: friendly identification, detection and track	1	16k
N	CP-642B/USQ-20 (30 bit, 4 μ s)	Navigation	1	32k
C1	CP-642B/USQ-20 (30 bit, 4 μ s)		1	32k
C2	CP-642B/USQ-20 (30 bit, 4 μ s)	NTDS: Rate-aided tracking, air traffic control, identification,	1	32k
C3	CP-642B/USQ-20 (30 bit, 4 μ s)	threat evaluation and weapon assignment, display, communications	1	32k
C4	CP-642B/USQ-20 (30 bit, 4 μ s)		1	32k
M1	MU-602(V)/UYK	Extended Core Memory Unit (ECMU) (642)		256k
CF	CP-789/UYK (18 bit, 4 μ s)	CFU: interface control and data conversion	1	16k
A1,A2	CP-848/UYK (18 bit, 2 μ s)	Precision tracking for aircraft landing control	2	16k (total)
W1	Mk 157 (16 bit, 1 μ s)	Missile fire control	1	16k

Future modifications to on-board carrier systems will include improvements in data link systems and command control communications systems equipment.

There are five CP-642B/USQ-20 computers (CVAN-68; alternate configuration is four CP-642A/USQ-20 and one CP-642B/USQ-20). This computer has a 30 bit word length, a 32k word memory, a 4 μ s cycle time (8 μ s for CP-642A), and an instruction set of 62 instructions. There are eight 32k 30 bit word executable instruction memory units available to four of the 642's.

There are one or two CP-789/UYK computers (Univac 1218); the second is designated the CFU. This computer has an 18 bit word length, a 16k word memory, a 4 μ s cycle time, and an instruction set of 98 instructions.

There are two CP-848/UYK (Univac 1219) computers, which are similar to the Univac 1218's. The 1219 has an 18 bit word length, an 8k word memory, and a 2 μ s cycle time.

Computer peripherals which support the operation of the four NTDS CP-642B computers include:

1. 1 paper tape unit, Signal Data Recorder (reproducer) RD-231/USQ-20,
2. 2 magnetic tape units, RD-243/USQ-20,
3. 2 system monitoring panels, C-3674A/USQ-20, and
4. 5 universal keysets MX-3195(V)/USQ-20.

5.2.2 Interrelation among Computers

The NTDS unit computer with the ECMU is the primary CDS data processing element. The Ship's Inertial Navigation System (SINS) computer and the BVP computer provide data to the NTDS unit computer over peripheral input/output (I/O) channels. The CFU interfaces with the NTDS unit computer over a peripheral I/O channel. The Univac 1219 computers of the aircraft landing system interface with the NTDS unit computer over one peripheral I/O channel.

Corresponding I/O channels of the four NTDS CP-642B computers are generally dedicated to the same interface function. A switching arrangement connects each particular interface to an I/O channel of one of the four NTDS computers. The four NTDS computers are interconnected by both intercomputer channels and peripheral channels. Two peripheral equipment simulators, CV-302/UYK, are required for the peripheral I/O channel interface.

In the past, the configuration of the four NTDS computers without ECMU had resulted in a large amount of intercomputer data transfer. This occurred because a substantial number of program modules located in more than one of the computers obtained data from or provided data to a peripheral connected to an I/O channel of one computer. The intercomputer data transfer is overhead, as it does not involve either mathematical or logical operations. The ECMU permits communication of each computer with the memory unit without intercomputer connection, solving the problem.

5.2.3 Functional Allocation among Computers

Four of the CP-642B computers are the data processing element of the NTDS. These computers are linked together by intercomputer and peripheral I/O channels and are designated as the NTDS unit computer, in association with the eight-unit extended memory. The NTDS unit computer provides rapid assembling and maintaining of target data and ATC data, performs mathematical and logical operations, presents situation summary displays to operators, provides recommended courses of combat direction action, designates target data to the missile system and to aircraft, and finally designates position data to the ATC landing system for final approach.

The fifth CP-642B computer supports the STNS as a peripheral system.

The first of the CP-789 computers is part of the BVP system. The second CP-789 computer is the CFU, which provides a data interface between the NTDS unit computers and the display system, the Keyset Central Multiplexer (KCMX), and several other computer peripherals.

The two Univac 1219 computers are part of the aircraft landing system, AN/SPN-42. Each computer performs a director feed-back function similar to that of a fire control system and supports a tracking channel of the AN/SPN-42 for close control during the landing evolution.

5.2.4 Functional Interfaces with Sensors

NTDS has the primary responsibility for the tactical processing of data derived from the CV sensor system preprocessor. All sensor data (with the exception of certain classified IFF data) are input to the NTDS operational program via operator action or by operator monitor at either general-purpose display consoles or special-purpose keyset equipment. Search radar video data are entered via the display system complex; electronic countermeasures data and fire control radar data are entered via the signal conversion equipment of the KCMX. Automatic (computer-to-computer) input of selected IFF data and automated search radar data input are accomplished through the BVP equipment and the pertinent preprocessing search radar computers (video processors), respectively.

5.2.5 Functional Interfaces with Weapons

NTDS/WDS provides the primary data interface with CV Weapon Systems. Target designation by NTDS computer to the missile systems is accomplished via the signal conversion equipment of the KCMX, which interfaces with the CFU or directly with the NTDS unit computer.

5.2.6 Functional Interface with Air-Traffic Control

CATC is integrated with the NTDS. The CATC function consists of all ATC operations except final approach, which is controlled by the AN/SPN-42 system. There are three subfunctions associated with CATC: departure, marshalling, and approach. Two NTDS operator consoles are used for approach control and one console each for marshalling and departure. One aircraft entry keyset is used with CATC to enter various aircraft data into the NTDS.

Approach control consists of aircraft control from the marshalling point through the landing pattern to start of final approach. Final approach begins at about 3 to 5 nm. At the start of final approach, the aircraft are designated by the NTDS unit computer to the AN/SPN-42 computer system.

Marshalling control consists of controlling aircraft upon arrival at the marshalling area, about 40 to 50 nm, and proper turnover of the aircraft to approach controllers.

Departure control consists of tracking aircraft launched from the ship until the aircraft are assigned to a tactical air controller.

5.2.7 Casualty Operation

NTDS computer casualty operation consists of operation with one, two, or three of the NTDS computers at correspondingly reduced levels, without the ECMU.

5.3 COMPUTER PROGRAM ARCHITECTURE

5.3.1 Naval Tactical Data System Computer Program

The NTDS operational program and its associated equipment suite comprise the operational equipment center of CV CDS's. As such, the NTDS supports command and control for the ship by supplying the ship's command and control operating personnel with systematically processed, and real-time evaluated, tactical situations of ownship and other members of the force and by specifying the actions recommended in response

to the input tactical environment. A recent significant additional feature of the NTDS operational program is the inclusion of a defense control capability against antiship missile threats. This control consists of the implementation of automatic threat recognition action and assignment of Sensor/Weapon Systems against targets that are considered imminent threats.

5.3.2 Naval Tactical Data System Program Architectural Structure

The NTDS operational program is a modular, multicomputer program that is coded and compiled utilizing the CS-1 and CMS-2 languages. Each module is named after a functional unit, i.e., it is allocated processing responsibility for a function or group of related functions. Module functional responsibility is often allocated according to equipment and software interface performance. However, the total processing of the data transferred across the interface is not necessarily assigned to the interfacing module but may be distributed via the executive between several modules dependent upon the utilization of the data. The Display (DS) module, which is responsible for servicing (performing the interface with) the consoles, is an example of this type of module, i.e., interfacing with many others through the software executive.

Several of the NTDS program modules are responsible for implementing functions required by all other modules in the program and by other elements of the NTDS. These modules provide executive control over all real-time and periodic processing references that are granted to each module; they provide the capability of transferring data among modules of the NTDS operational program and between the four CP-642B computers and the ECMU in which the modules reside; and they provide the means whereby control over system operation and system reconfiguration may be exercised by operational system personnel. The remaining modules that comprise the NTDS operational program are responsible for processing the information gathered from sensors, weapons, intelligence, ownship support system, and other units of the force, and for providing the information to the NTDS console operators in a meaningful format. By evaluating the data provided by the program modules via the console displays, NTDS personnel are capable of rapidly responding to any tactical situation.

Dynamic modular replacement (DMR) is a technique that allows an NTDS operational program to be reconfigured by the addition or deletion of certain modules from computer core when no ECMU is available. This can be accomplished during program execution without disruption to normal tactical operations. DMR helps overcome recent core limitation constraints on the size of the operational program, while providing the capability for satisfying several diverse mission requirements with a single computer suite. Modules that are entered into fixed core locations at program loading are referred to as resident modules. Modules that can be

dynamically added or deleted from the program during execution are referred to as transient modules. Transient modules are compiled in relative format at a standard base address. As in other NTDS ships, transient modules are entered into core from a magnetic tape unit. Approximately 20k words of one computer are currently reserved for transient modules, when no ECMU is installed.

The basic structure of all NTDS modules, resident and transient, includes a data section and an instruction section. The data section includes local data for module use only, executive interface data to be used in the transfer of Central Processing Unit (CPU) control to the executive, and a storage area for messages received from other modules via the executive. The instruction section includes a real-time (console) instruction set and, if appropriate, will also include a periodic (monitor) instruction set and/or an equipment (interrupt) interface instruction set. The executive system controls entry into a module's real-time, periodic, or equipment processor programs. Each module has a unique priority designator which indicates when CPU control will be transferred to its specific processing tasks. This designator is a part of the executive interface data contained in the module's data section.

5.3.3 Naval Tactical Data System Program Executive System

The NTDS executive system is constructed in four functional sections. These sections are designated as Common Control (CC), Executive (EX), Intermodule/Intercomputer (IMIC), and Data Update (DU). An identical executive system resides in each of the CP-642A computers used by the operational program without ECMU, and CPU and I/O processing in all computers proceeds independently and simultaneously. Control is transferred to the executive system of each computer after the program has been loaded and brought on line.

The executive system Common Control section contains a common data area and an area for common processing routines. These items can be referenced by any module, as required. The common data area contains mathematical routines such as sine, cosine, and square root. It also contains other routines such as those required for message data packing and preset operations. When ECMU is available, most of these tables are in the (shared) ECMU memory.

The Executive section is responsible for maintaining program control over all modules resident within its computer. It schedules all real-time and periodic references to each of the modules using that computer's I/O. Task scheduling is accomplished according to a predefined priority scheme that is based both on the module's servicing priority and on whether the required module task is a real-time (console) task or a periodic (equipment) task. The Executive section is made up of

three segments. These are a display initiation subexecutive, a real-time subexecutive, and a periodic subexecutive. The highest priority is given to display initiation tasks. Tasks are serviced in priority order for each Executive section cycle so that real-time tasks are not serviced if there are any display initiation tasks to be completed, and periodic tasks are not serviced if there are any real-time tasks to be completed. Display initiation tasks are executed only in the computer interfacing with the display system complex etc.

The executive system's Data Update section is responsible for entering, updating, and clearing data in the data stores area of the Common Control section or of the ECMU. Messages are transferred to the Data Update section via the IMIC section. Messages from any module that are addressed to the Data Update section are sent to the Data Update sections of all of the system's computers that do not have an ECMU. The structure of the Data Update section of the executive system is similar to that of the basic program module, and, in program execution, Data Update is given the highest priority for real-time processing. This ensures that program common stores are always updated at the first available opportunity.

5.3.4 Naval Tactical Data System User Module Functions

The modules of the CV NTDS operational program that serve equipment and console operators directly and a brief description of their primary functions are given in Table 5-2. There is no direct relationship between the program structure and either the NTDS functions (defined by the Functional Operational Design) or operator stations (consoles). Generally, more than one operator function will be accommodated at a program module. Program modules can perform operations related to more than one function, and several program modules can perform operations affecting a particular operator station.

5.3.5 Time and Core Requirements

The current CV NTDS operational program uses essentially all of the available time and core in the four CP-642B computers. The DMR capability was developed because there was not sufficient core for all the modules to be in the computers at once without ECMU.

Memory expansion equipment being installed will increase the ship's NTDS computer core capacity by 256k (the equivalent of eight computers). Additional memory, rather than additional computers, will be used to alleviate both a major core problem and a timing problem. The timing problem is caused primarily by the large amount of intercomputer data transfer required to transfer data among the modules and peripherals connected to each of the four USQ-20 computers without ECMU. The expanded memory will permit access to every location in ECMU by each

TABLE 5-2
CV NTDS PROGRAM MODULES

Module	Primary Function
Air Traffic Control	Provides ATC functions for the carrier. Supports the Departure Controller, Marshall Controller, and Letdown Controller console modes. Two versions of this module are available with different aircraft handling capacities.
Basic Training	Simulation of a realistic tactical environment for training purposes. Includes simulation of radar returns for display on consoles. Supports the Training Supervisor mode.
Beacon Video Processor	Provides interface between NTDS program and BVP equipment. Pre-processes target position data as automatically generated by BVP. Supports Selective Identification Feature (SIF) Tracker console mode.
Combat Systems Operability Test	Processes and prints out selected data extraction events.
Common	Provides storage areas required to contain those data stores and subroutines that are most frequently utilized by other modules.
Control Formatter Interface	Performs interface functions between the NTDS and CFU programs.
IMIC Communications	Transfers all intermodule and intercomputer messages.
Data Extraction	Controls the extraction and recording on magnetic tape of system operational data.
Data Update	Maintains the common data stores in each of the NTDS computers.
Display	Provides interface between console operators and the NTDS program via the display subsystem. Supports all console displays and pushbutton operations.

TABLE 5-2 (cont'd)

Module	Primary Function
Dynamic Modular Replacement	Master provides for modification of program configuration. Slave supports bookkeeping functions in non-master computers.
Electronic Warfare	Provides interface between NTDS program and ECM equipment. Supports EW supervisors.
Executive	Maintains program control and schedules all modules resident in computer.
Height/Size	Processes air-track height and size data inputs from Height/Size console mode.
Identification	Establishes the identity, class, and category of all local tracks based on manual and automatic inputs. Supports the Identification console mode.
Intercept Control	Supports intercept controller tasks for vectoring interceptors to attack positions. Calculates pursuit or collision geometries.
Link 4A	Provides an interface between the NTDS program and the Link 4A Communications equipments.
Link 14	Selects and formats NTDS tactical data items and supplies them for broadcast to non-NTDS ships in the force.
Link 11	Transmits data assembled by other modules on Link 11 terminal and routes data received from terminal to appropriate module for decoding and use.
Point Defense	Provides interface with Basic Point Defense Surface Missile Systems (BPDSMS). Provides target designations to BPDSMS and receiver repeat-back data from BPDSMS.

TABLE 5-2 (cont'd)

Module	Primary Function
Resident Control	Provides interface with System Monitoring Panel which is used for loading and maintaining the program, controlling system operation, and controlling DMR.
SPN-10/42	Interfaces with Automatic Carrier Landing System. Provides target designations of aircraft in letdown phase for final approach and landing control.
Surface Maneuvering	Supports the Command Bridge console mode which monitors all air, surface, and subsurface tactical situations as they affect ship's operation.
Surface Operations	Maintains position and velocity of ownship, special moving points, and fixed geographic points.
System Tracker	Encodes and decodes data transferred to and received from Link 11. Determines reporting responsibility for Link 11 tracks, decorrelation of local and remote tracks, and computation of gridlock and intership radar alignment corrections.
Threat Weapons Assignment	Performs threat evaluation on targets with respect to ownship. Performs weapons assignment and engagement functions for missiles, guns, interceptors, UV, chaff, active ECM, and passive ECM systems. Supports Force Weapons Coordinator, Flag Command, Ship's Weapon Coordinator, and Ship Anti-Missile Coordination console modes.
Tracking	Performs tasks associated with rate-aided tracking based on track position data entries. Supports Detector Tracker, Track Supervisor, Air Tracker, Surface Tracker, and SIF Tracker console modes.
Utility Processor	Processes selected General Purpose Function Code (GPFC) entries from operators requesting PPI symbology and data read-out amplification data or entering certain data.

computer. With the expanded memory, there will be no need for inter-computer data transfer after program load, and consequently the total required execution time will be greatly reduced. Also, a load-leveling technique used in the executive will permit balancing the processing load equally among all four computers, further reducing the timing problem by sharing CPU's among all non-I/O modules in ECMU.

5.4 SOFTWARE DEFINITION, DESIGN, AND IMPLEMENTATION

5.4.1 CV Naval Tactical Data System Software Definition and Design

FCDSSA(SD) designed, developed, and implemented the NTDS program for the CV Class ships. The development of this program used other FCDSSA(SD) NTDS programs as a baseline design, thus avoiding costly redevelopment and helping to keep NTDS programs uniform.

The documentation used for the definition and design of the CV NTDS program is summarized in Table 5-3. The purpose and content of each of these documents (as well as those shown in Table 5-4) are described in FCDSSA Instruction 5600.1C. As can be seen in Table 5-3, the documents fall into three major groups: Navy Requirements, System Specifications, and Program Specifications.

5.4.2 CV Naval Tactical Data System Software Implementation

The development or preliminary implementation phase consists of achieving a functional capability in a computer program and testing this capability to ensure that it satisfies the requirements of the system. During this phase, very few programming, hardware, or documentation change restrictions are imposed in order to keep the software flexible and minimize the costs of changes.

During the development of the CV NTDS program at FCDSSA, the documentation consists largely of functional descriptions with minimal changes to implementation methods. Interfaces between software and hardware and among modules are documented carefully, while the internal workings of the modules are usually documented in extensive listings from the high-level compiler used (CMS-2). The documentation used during implementation of the CV NTDS program is summarized in Table 5-4.

After a working program is obtained, the implementation is maintained with the Program Design Specification (PDS) and the program Technical Description Document (PTD), which is primarily the listings as annotated by programmers.

Certain programming standards were used in the CV NTDS program. These were largely related to the use of the NTDS executive and

TABLE 5-3
CV NTDS DEFINITION AND DESIGN DOCUMENTATION

Document Type	Document Name	Content
Navy Requirements	Tactical Operational Requirement (TOR)	Describes in operational user language all Tactical Data System (TDS) functional requirements that have been established for a given ship, aircraft, or shore-based command mission.
System Specifications	System Operational Specification (SOS)	Describes specific operational functions including details of system requirements for the required mission, doctrine, operating environment, and operational position. System constraints including hardware descriptions are also described.
	System Operational Design (SOD)	Describes a plan for the integrated system program. Contains all proposed program function core allocations, all subprogram definitions and their interfaces, and overall program data development.
Program Specifications	Functional Operational Specification (FOS)	Specifies each required action at each operator's position and the use of each peripheral's I/O capability. Data type and the processing and disposition with intercommunication and equipment interfaces are specified for each operator function and for each unit of peripheral equipment.
	Functional Operational Design (FOD)	Describes a functional design, in operator function terms, for each console (and mode) operator and peripheral equipment. The operator or equipment actions, data sources, control requirements, and control design and their interfaces are detailed.

TABLE 5-3 (cont'd)

Document Type	Document Name	Content
Program Specifications (cont'd)	Program Performance Specification (PPS)	Describes computer program (Executive system only) in terms of logical, functional, and mathematical language.
	Interface Design Specifications (IDS)	Used when two or more data systems are interfaced at the on-line interdigital processor level. Describes interchange message formats, content, timing requirements, originating signal source, and disposition of exchanged data.

TABLE 5-4
CV NTDS IMPLEMENTATION DOCUMENTATION (Program Description)

Document Name	Content
Program Design Specifications (PDS)	Contains the design details for the digital processor program in programming language.
Program Technical Description Document (PDD or PTD)	Contains the design details for each subprogram of the digital processor program in terms of programming logic and language. It presents the results of the programming effort, usually in extensive compiler output listings with comments.
Data Base Design (DBD)	Provides a detailed description of all data items that are required by more than one subprogram.
Program Package (PP)	Contains all items necessary for the processing agency to produce and maintain the computer program, including the source deck and listing, object program tape, an error-free assembler/compiler listing, and a cross-reference listing.

intermodule communications techniques, so that the executive system could be supplied as a standard package.

Thus, the production or final implementation phase takes the proven, functional design generated in the development phase and transforms it into a well-documented, standardized, maintainable program. This avoids recompiling for a different computer or in a different language or operating from a different executive, since the FCDSSA-developed CMS-2Q contains code generators for several Navy computers.

5.4.3 Program Generation and Library Facilities

FCDSSA has developed a four-bay UYK-7 time-sharing system called SHARE-7 which it uses for developing NTDS programs. SHARE-7 contains several compilers and debug aids. An NTDS library is maintained on disks that contain all the CV program modules in addition to the modules for several other ship classes. The content of this library is tightly controlled. The listings of the library are produced on microfiche and on tape at FCDSSA(SD).

The operational NTDS program for the CV is written in the CMS-2 programming language developed and maintained by FCDSSA(SD). The CMS-2 compiler is run on the SHARE-7 system (also maintained by FCDSSA(SD)). In the future, the FCDSSA(SD) program libraries may be recompiled to the UCMS-2 version of this language. This is a machine-independent language and FCDSSA has shown that its use will ease the NTDS program development efforts by permitting all applications modules to be used on different machines without recompiling or reprogramming.

5.4.4 Externally Driven Program Modification

The addition of the F-14 UHF data link reply operations capability to the CV NTDS program provides an illustration of the normal workings of the definition, design, and implementation stages of FCDSSA. This modification involved changing the intercept control and Link 4 modules to provide for the new F-14 downlink capability.

The first step was to modify the System Operational Design (SOD) describing how the new requirements affected the old modules. These descriptions were specific about hardware changes but general about software changes, dealing in capability only. The second step was to change the appropriate Functional Operational Specifications (FOS) to describe the required changes in console actions and operating procedures. The affected Functional Operational Designs (FOD) were also modified at this time. A contractor was then asked to provide people to accomplish the program design and coding changes. The revised documents were used to direct the programming effort. The program was written, tested by FCDSSA(SD) using simulated F-14's, and then taken to the Pacific Missile Range (PMR) test facility at Pt. Mugu for testing

with the actual F-14. After 6 months of testing, a test version of an operating program was accepted along with annotated copies of the FOD's and other documents. This completed the development phase.

The production phase consisted of producing a clean, formal FOD and PDS and recompiling the program, validating it, and entering it into the FCDSSA(SD) control library. This completed the production phase, and the changed modules went into the controlled in-house maintenance phase.

During the development phase, FCDSSA did not try to change the details of implementation by requiring structured programming or using other new and unproven techniques. FCDSSA believed that structured programming could be efficient in off-line support programming, such as test programs, but not in tactical applications programming updates to the existing NTDS program libraries. In general, the programmers were permitted to implement the functional requirements of a subprogram in any way they chose, within the limitations imposed by the executive and language standards as specified in the FCDSSA(SD) Program Production Handbook. The acceptance of a program by FCDSSA(SD) is based on its performance to the operational function requirements and not its particular coding sequence. Core and time budgets are constraints applied in the SOD; within these constraints and those of the compiler and library GFE and the module interface standards (IMIC), programming innovation and reliability are encouraged and evaluated for contractor fee award, but not mandated.

5.5 SOFTWARE VALIDATION AND INTEGRATION

5.5.1 Validation and Integration Approach

The primary objective of validation and integration at FCDSSA(SD) is to verify that the software produced satisfies the functional requirements specified by the FOD. The process consists of integrating the software into the operational program and testing the program functions against the actions specified in the particular FOD. The design of the software is not considered during the functional validation process, having been accepted at the program level during instrumented program acceptance tests with the GFE executive and IMIC standards given.

Testing of the software against the FOD consists of validating that each operator function is performed correctly. Test inputs consist of those expected during normal operation; they also include parameter out-of-range conditions, as all software is designed to check each parameter for the appropriate range of values in the peripheral input tests of a given program.

Functional validation is restricted basically to testing against the FOD; as long as the FOD is satisfied, later changes, if any, are made onboard the ship. It is economical to verify the FOD at the FCDSSA(SD) facility and to make any unspecified changes during ship-board integration.

5.5.2 Software Validation and Integration Procedures

FCDSSA has an extensive test and validation facility, with capabilities for scenario generation, live mock-up operation, peripheral simulation, and nonreal-time and real-time input generation from operational consoles and data links. The colocation of FCDSSA(SD) with the training facility permits sharing equipment.

Software test and validation is accomplished by five sequential phases, ranging from basic debugging by the contractor to real-time testing of the integrated software system in an operational mock-up. The five phases and a brief description of each are

1. Phase 1, Compile — debugging of the compiled program only.
2. Phase 2, Emulate — debugging using a host computer emulator to execute the program in SHARE-7 using on-line dedicated operational computers.
3. Phase 3, Dedicated on-line simulation for program acceptance — exercising the program using the real executive with scripted intermodule messages in nonreal-time.
4. Phase 4, Nonreal-time function and system test — live mock-up of the system with nonreal-time program execution of live scripted console actions (simulated). Console inputs are scripted while parametric inputs are tested for out-of-range conditions; otherwise no variation of quantitative tests are performed.
5. Phase 5, Real-time system test — live mock-up of the system using live inputs, as available, and performance of quantitative tests with operators from a scenario taken from the SOD and FOD. The user manuals are validated during this exercise.

Phases 1 and 2 are debug and verification procedures performed by the contractor; FCDSSA receives the software under the condition that these phases are completed. Phase 3 consists of FCDSSA utilizing a UYK-7 and two USQ-20 computers to execute the software under control of the real executive with scripted simulated intermodule messages. Currently Phase 3 support software is being expanded. Phase 4 currently is

the function test phase at which initial validation of the software capability by FCDSSA occurs. Phase 5 is the final test of the software performed in live mock-ups at the FCDSSA facility. Live inputs are used when the required equipment is made available at the facility being shared with training. If the equipment is not available, its operation is either simulated, or the necessary portions of Phase 5 testing are performed onboard the ship when the equipment is installed and program delivery and onboard training is being conducted by FCDSSA(SD).

Plans for the future include increased use and improvement of Phase 3. It is intended that Phase 3 be the primary validation through which FCDSSA will accept or reject the modular software, rather than relying on Phase 4. Phase 3 uses the real executive and should include quantitative tests. The test system which will support Phase 3 testing is designated the "Multi-Module Test Tool" (MMTT).

The SHARE-7 operating system supports test Phases 1, 2, and 3. SHARE-7 software runs currently in a UYK-7 computer. Through SHARE-7, a program can be compiled and the emulator called to execute the program (Phase 2). The process consists of partitioning the UYK-7 or running with two USQ-20 computers dedicated on-line, depending on whether the target (ship) has UYK-7's or USQ-20's and on the degree of execution required.

Computer equipment associated with validation and integration includes six groups of computers, each group with symbol generator, video simulators, and analog input generators. In general, eight computers are required to simulate a ship mock-up, four for the object program and four for full simulation. The ECMU has been added to the simulation facility, and it released two or three of the simulation computers.

Table 5-5 summarizes the documentation used during the testing stage (as indicated previously, the documents are described in more detail in FCDSSA Instruction 5600.1C).

Once the software is in testing, it may be changed, when required, only by the test group using the in-house configuration control system.

5.6 SOFTWARE ACQUISITION MANAGEMENT ORGANIZATION AND METHODS

5.6.1 Management Information

The acquisition of the NTDS program for the CV was controlled by FCDSSA throughout its development, production, and maintenance phases. This information is summarized in Table 5-6.

TABLE 5-5
CV NTDS TESTING DOCUMENTATION

Document Name	Content
Test Plan (TP)	Identifies the program to be tested for quality assurance and details the schedule of milestones for the test, including simulations, equipment, and personnel requirements.
Test Specification (TS)	Identifies the capabilities or program functions to be tested and the test environment used.
Test Procedures (TPR)	Describes the test exercise script of events.
Test Report (TR)	Describes the observed test results.

TABLE 5-6
SOFTWARE MANAGEMENT INFORMATION, CV CLASS SHIPS

Program Status	Deployed
Program Manager	FCDSSA(SD)
System Contractor	None
Software Contractor	Various plus in-house
Type of Contract	Level of effort (tasks as necessary)
Maintenance Agent	FCDSSA(SD)
Validation Agent	FCDSSA(SD)
Integration Agent	FCDSSA(SD)
Software Deliverables	Phased program version and documentation deliveries

5.6.2 Software Contracting Methods

The NTDS program for the CV, as for all software at FCDSSA, was developed at FCDSSA, using in-house personnel to generate the FOD and level-of-effort contracting and in-house personnel to generate the program design and code. The contractor worked at the FCDSSA facility, which provided all the necessary equipment and support software. In FCDSSA's 15 years of experience, the results of this type of contracting have been cost-effective. These results can be contrasted with programs that were acquired under end-item contracts, with only the program code as a deliverable. The end-item contracting resulted in extremely costly programs that were difficult to maintain and unacceptable to the users.

FCDSSA always recommended separately funding each component task in the software acquisition process, with each task tied to a deliverable document. Funding of each task would be contingent on the review and acceptance of the previous component task. The documents generated by FCDSSA in each phase of software acquisition have been described in Tables 5-3, 5-4, and 5-5. This system of documents is thus used as a basic management tool, providing technically competent in-house personnel with a vehicle to direct and control the effort continuously at the funding, schedule, and technical performance level. The Fleet Officers representing the user permit the FCDSSA effort to be effective as well as cost-efficient.

5.6.3 Test and Evaluation Organization Structure

The Test Department handles Phases 4 and 5 (refer to Section 5.5.2) of software validation and integration, while the production department handles Phases 1, 2, and 3. There are five divisions within the Test Department; basically, two provide test support and one each provides configuration control, delivery, and peripheral device diagnostics. The five divisions are

1. Change Control
2. Evaluation and Analysis
3. Simulation and Test Support
4. System Test and Delivery
5. Diagnostics

The Evaluation and Analysis division as well as the production department uses Phase 3 testing. A large part of testing at this level consists of hardware/software integration, i.e., interface testing, timing,

and the evaluation of the software operating with the hardware. The Simulation and Test Support division supports Phase 4 testing (nonreal-time, mock-up). The System Test and Delivery division performs Phase 5 testing (real-time system test) and concludes at sea on-board. The FCDSSA organization separates function testing from system testing by department. The Diagnostics division provides all necessary diagnostics for device and peripheral checkout and testing and on-line operational program exercises prior to delivery and handover.

5.6.4 Management Findings

Each phase of the NTDS program for the CV has gone through three distinct life-cycle stages: development, production, and maintenance. FCDSSA believes that all software acquisition should include provisions for each of these stages. Each stage has different requirements and goals, and they should not be combined, but the ultimate user should be in control from the beginning, and he should be the sole agent for declaring the software completed.

FCDSSA considers that in all software acquisition efforts the ultimate user (or his designated agent) should direct all three stages of software and should have technical, fiscal, and managerial control over it. The ultimate user is the Navy office that generates the requirement for the software. The users fall into the three categories of Combat Direction Systems (CDS), weapon or sensor control systems, and automatic data processing or management information systems. FCDSSA has responsibility for some examples of all three cases, but primarily the first (CDS). The CV program and other programs that were developed under FCDSSA control resulted in maintainable programs that met the functional requirements written by FCDSSA, since they were the users. On the other hand, the programs that were developed by NAVMAT contractors and then turned over to FCDSSA for maintenance were always more costly to develop and difficult to maintain, because the user was not considered in the early stages of development. Only the user is aware of the real functional requirements of the system. He is aware of the documentation and standardization requirements that are necessary to operate and maintain the software. He is also aware of the facilities available for maintenance. Therefore, FCDSSA believes that the user is the best agency to make system trade-offs based on life-cycle costs. These costs should not be partitioned among various Navy sponsors because this would prevent making these trade-offs, the lack of which has resulted in the costly and unusable examples so frequently cited.

5.7 OPERATIONAL SOFTWARE MAINTENANCE

FCDSSA(SD) has had the responsibility for developing and maintaining all NTDS CDS software for the Pacific fleet since 1961. Since

the programs are both produced and maintained by FCDSSA(SD), there is no interorganizational transfer from production to maintenance, and therefore no cost or coordination required to achieve it.

The SINS program and the SPN-42 program were not produced and are not maintained by FCDSSA(SD). No problems have been experienced with either of these systems when interfacing to the NTDS, and the "user control" dictum is successful in these examples as well.

The maintenance phase consists of making appropriate modifications and additions to update the program first generated in the production phase. This task was made simple at FCDSSA because the standards and documentation used by the development and production phase were designed with life-cycle maintenance in mind. Table 5-7 shows the documentation that is essential during operational maintenance of CDS software.

TABLE 5-7

CV NTDS OPERATIONAL MAINTENANCE DOCUMENTATION (User Narrative Group)

Document Name	Content
Computer Operator's Manual (COM)	Describes control requirements and operating procedures necessary to successfully initiate, run, and terminate the subject system. Also describes diagnostic or maintenance programs in support of the operational program.
Program Design Manual (PDM)	Provides documentation for the computer user of the program structure and procedures for adding, modifying, or deleting portions of the program.
Command and Staff Manual (CSM)	Provides senior officers, operation planners, and all TDS operational personnel with a basic, non-technical description of the data system program capabilities.
System Operator's Manual (SOM)	Provides a single reference for individual operator training and combat station function, in sufficient detail that no other user document is necessary. Also serves as a handbook for trained operators.

5.7.1 Changes

Each particular CV program is designated by a model and phase number, and a ship number. A model change involves a change in Link 11 message formats. The program can also be restructured when a model change occurs. A phase change typically occurs every 2 years and incorporates into the program all patches and minor changes that have accumulated in that time but does not restructure the program.

5.7.2 Trouble Reports

Trouble reports onboard ship occur at a rate of about one per week for the first month of a newly installed program. The source of troubles, in the vast majority of reports, is the hardware or misinterpretation of the user documentation. On-board program patches to suit particular ship's company are encouraged, provided such patches are sent to FCDSSA for the record. An unpatched copy of the program as delivered is secured by the ship's officers before the delivery team leaves, so that any ship problems can be duplicated at FCDSSA for analysis and correction.

5.8 HIGHLIGHTS

Software breadboarding was used extensively in the development of the F-14 capability in the CV program. FCDSSA(SD) recommends this in all new programs, to prevent redesign and slipped schedules.

(MP1)

FCDSSA(SD) shows cost-effective results with its policy of in-house development using level-of-effort contracting. FCDSSA personnel cite programs acquired under end-item contracts, with the program code as a deliverable, that have resulted in costly programs that were difficult to maintain due to design or documentation incompatibility with the FCDSSA facility and procedures since FCDSSA contracts for a software capability rather than a computer program. Separate funding is recommended for each task in the software acquisition process, with each task tied to a deliverable document. Funding of each task would be contingent on the review and acceptance of the previous task. (MP3,SE3)

In the development of the CV NTDS program, FCDSSA(SD) used a sequence of milestones through the analysis, design implementation, integration, test, and review process. Each milestone was associated with a specific deliverable document or program, and each was separately evaluated and award fee paid accordingly. In-house capability is retained as a back-up in the event of contractor failure, but since small components are contracted, no catastrophic failure can occur. (AP1)

FCDSSA(SD) uses support tools and facilities and periodically updates its support software. The most recent operating system, designated SHARE-7, operates in a UYK-7 computer and contains compilers, host-computer emulators, and debug aids. SHARE-7 is also used during the first phase of software validation and integration development at the program level. (IP1)

FCDSSA(SD) has an extensive test and integration facility which it shares with training. It provides capability for live mock-up of systems and software under test. There are provisions for nonreal-time and real-time operation, peripheral simulation, operator input or simulated operator input, and use of operational systems hardware. The FCDSSA(SD) Test Department provides test support, configuration control, delivery, and diagnostics. (IP3)

FCDSSA(SD) has acted as an agent for the NAVMAT Program Manager in some software acquisition. FCDSSA personnel cited their knowledge of operational requirements and believe it to be essential to developing an effective CDS program. They were able to make tradeoffs based on total life-cycle costs because of their awareness of the total requirements. They strongly recommend having a user agent for the Program Manager involved throughout any Weapon Systems software acquisition process. (MS2)

Since FCDSSA(SD) is both the developer and the operational support agent, there is no transfer or duplication of either support software or of test and integration facilities. No cost or coordination is required. (MS3)

6. AEGIS WEAPON SYSTEM

6.1 GENERAL SYSTEM DESCRIPTION

The AEGIS Weapon System is a fast-reaction, high-performance antiair warfare (AAW) system that directs the Standard Missile against air and surface targets. It is an integrated shipboard detection, command, and weapon control system that is being engineered for installation in a wide variety of ship classes.

The AEGIS mission as a large-scale automatic system will be to provide the Fleet with a wide area surface-to-air and surface-to-surface defense through the 1980's and beyond, by countering aircraft, antiship missiles, and launching platforms. When used with long-range surface-to-surface cruise missiles and extended range surface-to-air missiles, the system will, in addition, provide the Navy with a major offensive surface strike capability.

AEGIS system development includes construction of two Engineering Development Models (EDM's) prior to construction of the first operational ship. The first development model (EDM-1) has been constructed and is currently serving aboard the USS Norton Sound as a test bed. The EDM-1 system is a limited performance system intended to provide verification of critical AEGIS capabilities.

The second development model (EDM-3C) will be installed in the land-based Combat System Engineering Development Site (CSEDS) as a prototype of the operational system. EDM-3C will provide verification of system engineering, interfaces, ship design support, and operational computer programming.

The major elements of the AEGIS Weapon System are a multifunction phase-phase array radar, weapon control and fire control systems, missile, launching system, command and decision system, and operational readiness test system.

The combat system for an operational AEGIS ship will be a federation of the AEGIS Weapon System with complementary AAW systems, antisubmarine warfare (ASW) systems, and Strike weapons. Variations in system configuration will allow system adaptation to a variety of cruiser and destroyer class ships.

6.1.1 AEGIS Acquisition History

Requirements and conceptual definition for an Advanced Surface Missile System were derived during an intensive Navy/industry study conducted in 1963 under the direction of Rear Admiral F. S. Withington (Ret.).

APL/JHU assisted the Navy in the conceptual design of the AEGIS system, addressing special effort to the more difficult technical requirements. Design, development, and demonstration of the essential elements of the multifunction array radar were accomplished at APL and provided a firm basis for a Full Scale Development of this new radar. In April 1968, Development Concept Paper 16 was signed by the Secretary of Defense, and DSARC I approval was given for initiation of Contract Definition. In 1969, following competitive proposal submissions by Boeing, General Dynamics, and RCA, a contract was awarded to RCA for the Engineering Development of the AEGIS Weapon System.

Program milestones A and B for Preliminary Design and Critical Design Reviews (PDR's and CDR's) were completed on schedule, and in October 1973 completion of land-based testing at the RCA plant signalled completion of milestone C.

During the initial engineering phase, program decisions were made to develop a functionally modular computer program and provide a Tactical Executive Program structured for AEGIS. The specifications and planning reflected strong emphasis on the software acquisition procurements.

Installation and tests at sea aboard USS Norton Sound have been successful and have generally supported program decisions made prior to and during the design reviews.

In June 1974, DSARC IIB endorsed the program and supported acquisition of the AEGIS system. Subsequent planning has concentrated on the selection and approval of AEGIS ship classes and on the detailed definition of the CSEDS.

6.1.2 Baseline System Configuration

The major elements and operation of the AEGIS Weapon System are represented in Fig. 6-1.

The multifunction array radar, AN/SPY-1, conducts area search, automatic target detection and tracking, precision tracking of targets selected for engagement, and midcourse command guidance communication with the Standard Missile (SM-2). The complex operations of this radar are controlled by a four-bay memory-shared suite of AN/UYK-7 computers, the current standard computer for new surface tactical systems.

An identical four-bay AN/UYK-7 configuration is used in the Command and Decision System (C&DS) Mk 1 to provide tactical decision support, operator interfaces, and data link with other units, and, as shown later, to interface with other sources of tactical data.

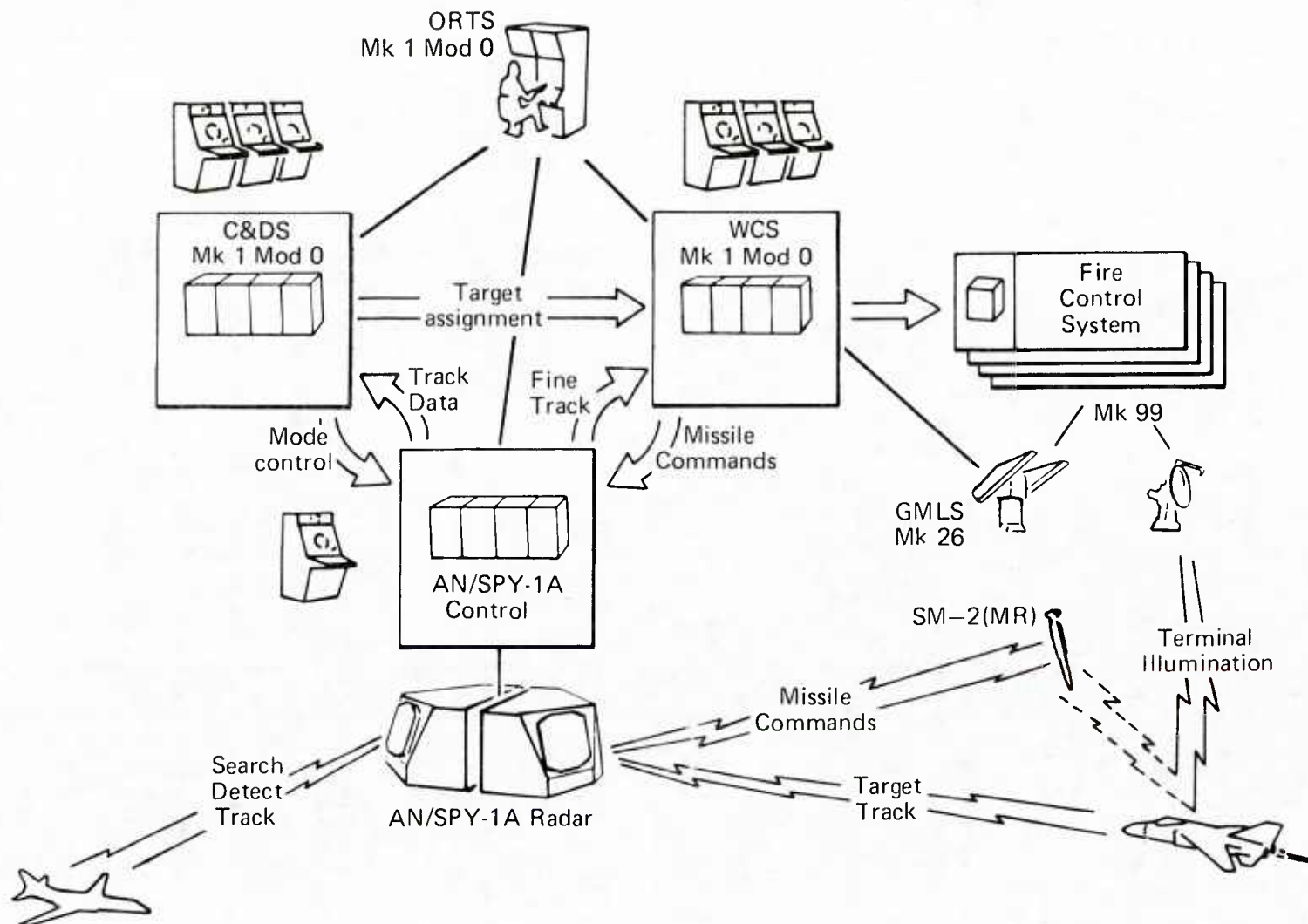


Fig. 6-1 AEGIS Weapon System, Mk 7

A third identical AN/UYK-7 suite is used in the Weapon Control System (WCS) Mk 1 to provide weapon engagement assessment, scheduling, and control.

The above three AN/UYK-7 suites are supported by a disk memory, available to all suites through a multiplex unit, that contains contingency computer programs and training computer programs. The disk also contains about 2 million words of overlay Operational Readiness Test System (ORTS) Mk 1 computer programs and fault isolation data. The central control of ORTS, which conducts continuous system availability testing and provides automatic isolation of detected faults to replaceable unit level, is located in an AN/UYK-20. Control of specific ORTS testing is allocated among all three AN/UYK-7 computer groups.

Precision control of the target illuminators is allocated to dedicated AN/UYK-20 computers in the Fire Control System (FCS) Mk 99. The AN/UYK-20 is the current standard minicomputer for surface tactical systems. The numbers and models of the launching system and the director/illuminator are adaptable to different ship configurations. The illuminators are slaved to AN/SPY-1 tracks.

Operator control of the system is effected through general-purpose consoles of the AN/UYA-4 data display group. Ten to eighteen consoles may be used, depending on ship configuration and mission. These are supplemented by the ORTS test and monitor console and by special-purpose consoles or panels within interfacing systems.

6.1.3 Engineering Development Model 1 Configuration

As shown in Fig. 6-2, EDM-1 is a scaled down version of the baseline system. Each of the primary system elements is implemented. The system is limited to a single AN/SPY-1 array face, one launching system, and a single illuminator (with tracking capability but used operationally only in the slaved mode).

[Changes in system nomenclature should be noted for understanding the following discussions. The Command and Control (C,C) System Mk 130 of EDM-1 is functionally equivalent to the C&DS Mk 1 of the AEGIS baseline. The Weapon Direction System (WDS) Mk 12 of EDM-1 is functionally a subset of the baseline WCS Mk 1, but includes computational functions that are allocated in the baseline to the FCS Mk 99.]

EDM-1 uses unit-computer configurations of the AN/UYK-7 computer rather than memory sharing. Two components support control of the single AN/SPY-1 array. The C,C system uses a two-frame AN/UYK-7 complex

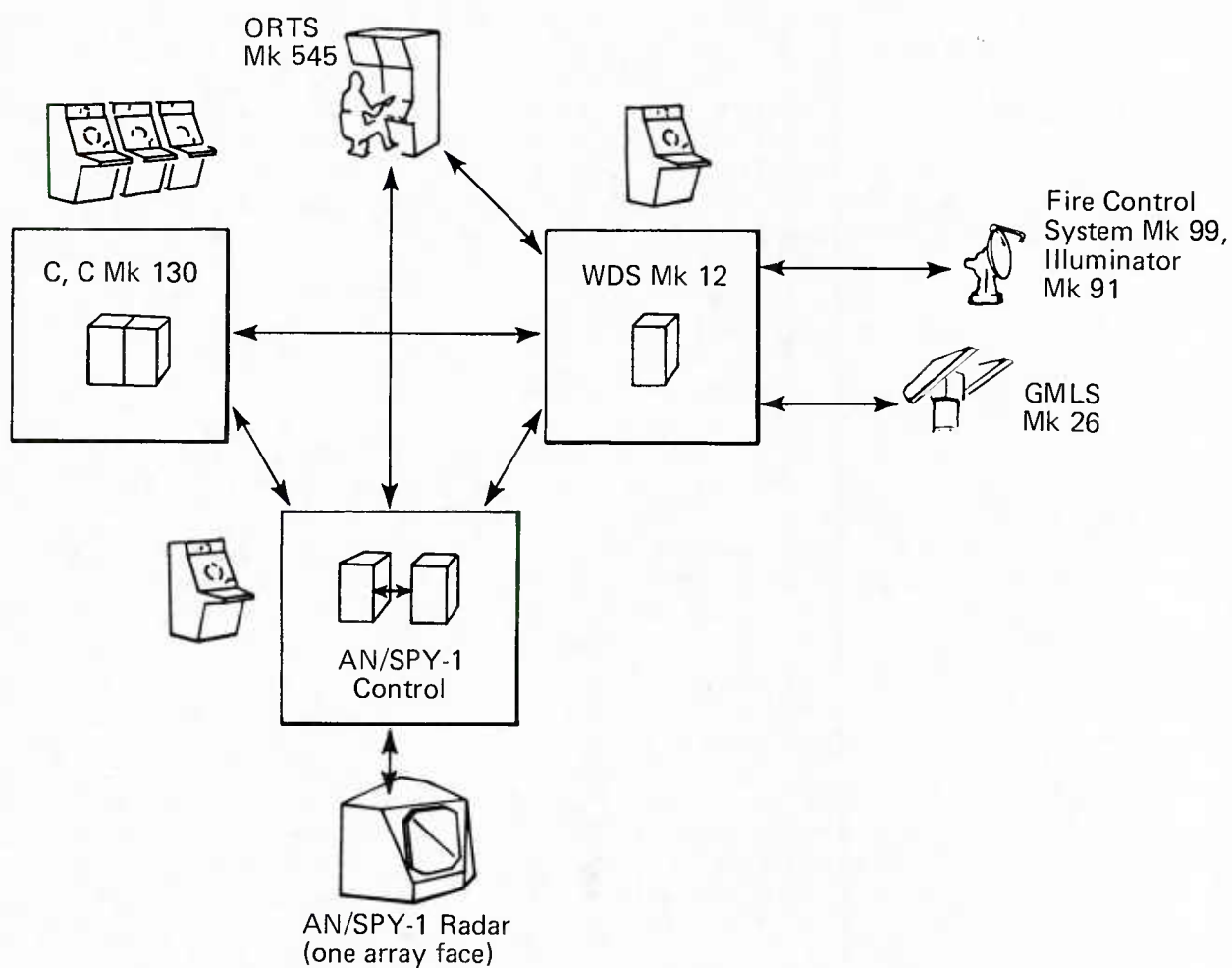


Fig. 6-2 AEGIS Weapon System (EDM-1)

with one central processor and extended memory. The WDS uses a single AN/UYK-7 computer that incorporates launcher and illuminator control as well as weapon scheduling.

A simplified version of the ORTS is used in EDM-1, covering fault detection in the AN/SPY-1 radar and a portion of the WDS. The EDM-1 ORTS includes the central test and monitor console, a monitor and status cabinet in the radar deckhouse, data acquisition assemblies, and associated computer programs.

EDM-1 was initially designed to be capable of target engagement only with the Standard Missile-1 (RIM-66B-2). Extensive testing was conducted using this missile. Subsequent modifications were made to the system and the computer programs to enable the at-sea testing of Standard Missile-2 (RIM-66C-1) now in progress.

Five general-purpose consoles of the AN/UYA-4 data display group are used for operator control of EDM-1.

6.1.4 AEGIS Ship Combat System Configurations

To provide all requisite functions for a combatant ship's Weapon System, the AEGIS Weapon System must be interfaced with additional sensors, communications, weapons, and support systems. Some variation in these interfaces across various ship installations must be expected and is planned for. The baseline system design is directed toward a maximum cruiser configuration, from which controlled system variants can be derived. Figure 6-3 represents the design baseline for the AEGIS ship combat system.

6.1.4.1 Sensor Systems

The AN/SPY-1 radar is the primary air sensor as well as the primary fire control radar on an AEGIS ship. It provides rapid horizon search and long-range and high-angle coverage. The SPY-1 radar reports data on a large number of simultaneous tracks. Its resources are adaptable to the environment and the tactical situation.

The Identification Friend or Foe (IFF) Interrogation System AN/UPX-29 is controlled by the special-purpose AN/UPX-24 digital processor. It can be directed to perform rapid secure-mode interrogations. It is compatible with the worldwide IFF military and commercial cooperative identification system.

2D Air Search and Surface Search radars, coupled with automatic detection and tracking (ADT) systems, provide auxiliary detection and tracking capability. Use of an AN/UYK-20 minicomputer in each ADT system provides a standard interface and an alternate source of track data.

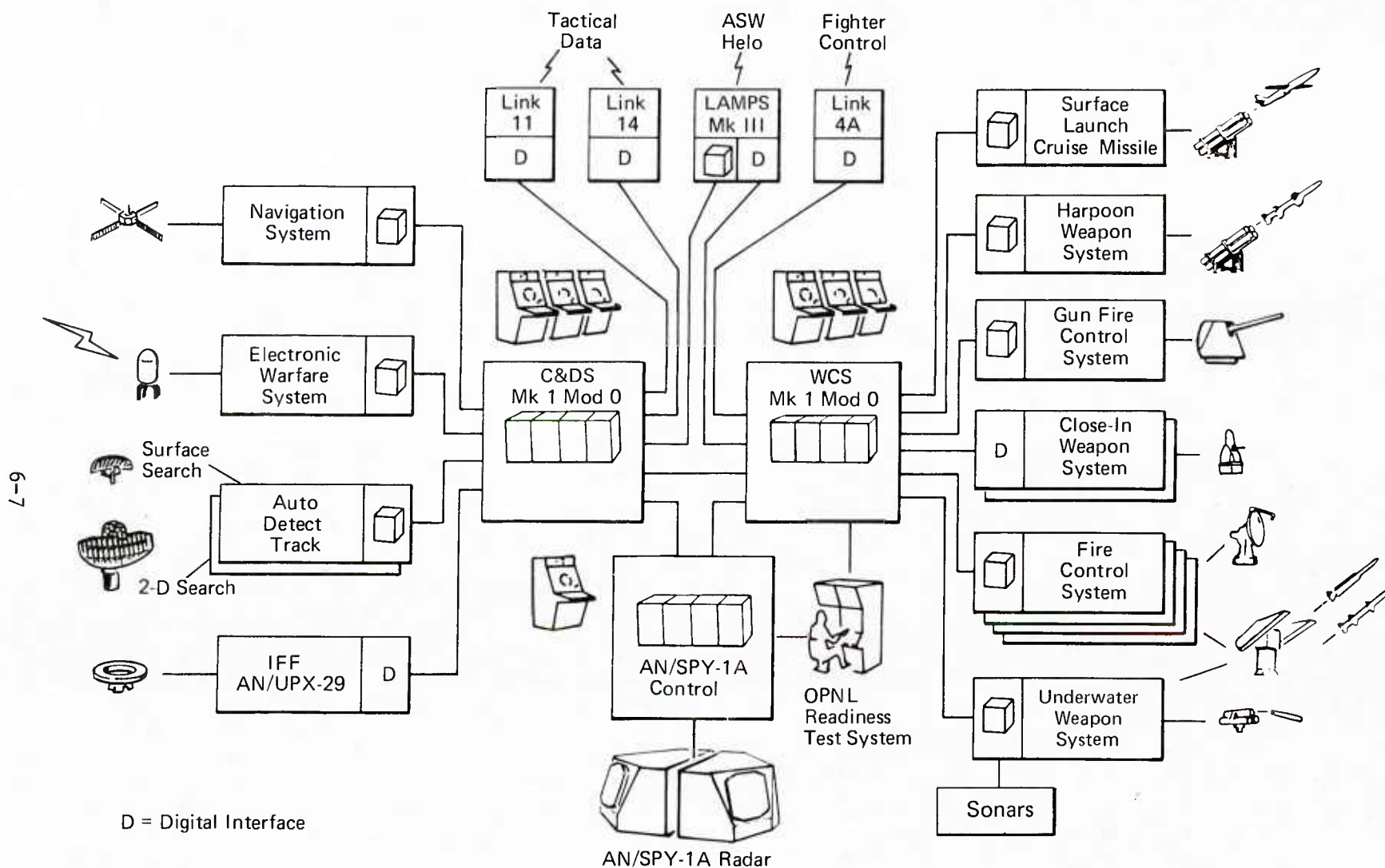


Fig. 6-3 AEGIS Ship Combat System

An Electronic Warfare System (EWS) will be used and may have reactive capabilities as well as sensing. The expected interface is with a minicomputer via standard Naval Tactical Data System (NTDS) channel.

A Navigation System must provide both ship's attitude (roll, pitch, heading) and ship's position to the combat system. A system is under study that uses a dedicated AN/UYK-20 minicomputer to integrate navigation system elements and provide continuous updated navigation data reports.

The sensor control function, accomplished within the C&DS, consists of the coordinated use of the ship's sensor resources and the merging of available data into a consolidated track file. The data must be used both in tactical decision making and in data-link reporting to other combatant units.

6.1.4.2 Tactical Data Links

Full exploitation of AEGIS capabilities in a coordinated task force may require the development of new data link capabilities for weapons control. Requirements studies on this subject are in process. For current design planning, tactical data link A (Link 11), Model IV, is adopted as a baseline. A teletype link (Link 14) capability will also be provided for communication with non-Tactical Data System (TDS) units.

The links dedicated to control of AAW and ASW aircraft (including Light Airborne Multipurpose Platform System [LAMPS]) are under the management of the WCS.

The data links are digitally controlled, have the standard NTDS interface with the system computers, and use the combat system Exterior Communication System to transmit and receive signals.

6.1.4.3 Weapons

AEGIS provides the primary AAW weapon, Standard Missile-2 (Medium Range), which acts in force area defense, self-defense, and short-range surface engagement roles.

Supplementing the AEGIS air defense is the Close-in Weapon System (CIWS), which provides a final defense against penetrators of the missile envelope. The CIWS is a self-contained system, but can be configured to accept target designations from other data sources.

ASW capabilities are provided by the LAMPS helicopter, the AN/SQS-53A sonar, the AN/SQR-19 towed array, and the Underwater Weapon System (UWS). LAMPS is both a data source and a weapon delivery platform and thus has interfaces with both C&DS and WCS computers. The AN/SQS-53A and AN/SQR-19 are on-board sensors. The AN/SQS-53A interfaces with the Mk 116 to provide sonar tracks to WCS and C&DS as well as to provide Target Motion Analysis (TMA) solutions for underwater fire control. The AN/SQR-19 provides passive track data to C&DS via voice. The UWS is controlled by the Underwater Fire Control

System Mk 116, which uses a single-bay AN/UYK-7 computer. This system controls both torpedo launch and ASROC missiles. For ASROC launch, the AEGIS Mk 26 launching system is switched to UWS control.

Strike capabilities are provided on the appropriate ships by the Harpoon Weapon System and by longer range tactical cruise missiles. The system baseline provides canister launchers for these missiles. Harpoon engagement is controlled by a dedicated computer that is incorporated in the Harpoon control console. The cruise missile system is expected to have a similar dedicated computer.

Various Gunfire Control System (GFCS) approaches have been investigated for the control of 8"/55 or 5"/54 guns in both air and surface modes. The baseline is the GFCS Mk 86, which uses a one-bay AN/UYK-7 computer and three special-purpose control consoles.

6.1.4.4 Combat System Integration

As seen in the previous discussion, the systems approach has been to allocate coordination functions to the AEGIS C&DS and WCS, but to distribute control processes to dedicated computers within the various weapon and sensor systems. This approach is expected to carry a number of benefits, among which are

1. Standardization of interfaces;
2. Controlled distribution of design responsibility;
3. Use of existing systems, where applicable, with minor adaptation only; and
4. Minimum impact on the system design from adaptation to various ship installations or incorporation of new interfacing systems.

Standard computers, computer peripherals, support computer programming, and operator consoles are used throughout the system, with exceptions being made where an existing system design can be used with minimum change. Data and control interfaces in nearly all cases use the digital NTDS standard (MIL-STD-1397).

6.1.4.5 Projected Ship System Diagram

Figure 6-4 represents an AEGIS operational ship configuration and shows the functional relationships among system elements. Any given computer in the diagram (e.g., C1) can be referenced via Table 6-1.

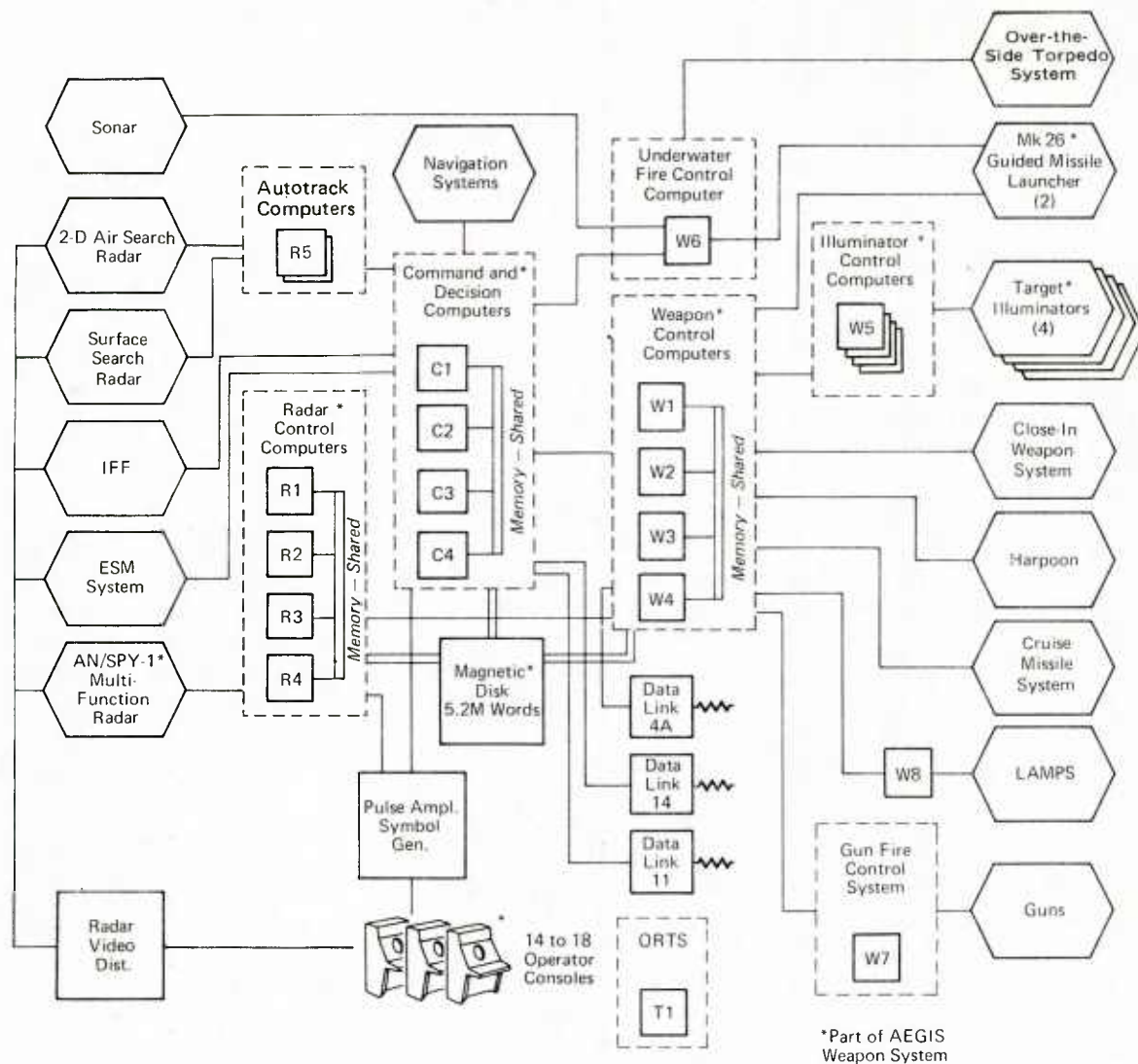


Fig. 6-4 AEGIS: Projected Ship System

6.2 COMPUTER SYSTEM ARCHITECTURE

6.2.1 Computer Characteristics

Table 6-1 details the computers, gross computer characteristics, and major allocated functions for a representative AEGIS operational ship configuration. Unit designations (e.g., C1) are keyed to the system diagram, Fig. 6-4. In addition to the four AEGIS AN/UYK-7 suites and illuminator control computers, dedicated computers are shown for underwater battery fire control, the ADT's with the auxiliary 2D radars, the GFCS, and LAMPS. Additional dedicated computers may be found embedded within the systems that will interface with AEGIS.

TABLE 6-1
AEGIS SHIP COMPUTER SUMMARY

Unit	Type	Function	Pro- cessors	Memory
R1, R2, R3, R4	AN/UYK-7 (32 bit, 1.5 μ s)	Radar control, search scanning, automatic tar- get detection and track, communication with guided missiles	4	256k
C1, C2, C3, C4	AN/UYK-7 (32 bit, 1.5 μ s)	Multisensor data correla- tion and management, iden- tification, threat evalua- tion and weapon assignment, display communications, surface operations	4	256k
W1, W2, W3, W4	AN/UYK-7 (32 bit, 1.5 μ s)	Weapon direction and fire control, air intercept con- trol, ASW support, LAMPS support, launcher control	4	256k
W5	AN/UYK-20 (16 bit, 750 ns)	Illuminator control	4	64k each
R5	AN/UYK-20 (16 bit, 750 ns)	Auto detection and track from beacon and 2D digit- ized video data	2	32k each
W6	AN/UYK-7 (32 bit, 1.5 μ s)	Underwater battery fire control	1	48k
W7	AN/UYK-7 (32 bit, 1.5 μ s)	Gun fire control	1	48k
W8	AN/UYK-20 (16 bit, 750 ns)	LAMPS control	1	32k
T1	AN/UYK-20 (16 bit, 750 ns)	ORTS	1	48k

Computer peripherals will include: two (for redundancy) mass storage disk memories, digital system clock, magnetic tape units for data recording, and an input/output (I/O) console. Provision is made for centralized computer control and initialization at the ORTS test and monitor console. In addition, a conversational terminal and printer will be used with each computer suite during system development.

Computer resource allocations (throughput, memory, and I/O channels) have been made within the TADSTAND-5 20% reserve requirements. In throughput and memory, an additional reserve of 20% has been retained for design margin. The resource allocations include reservation for planned "space and weight" systems.

6.2.2 General Considerations

AEGIS has moved further toward full computer control of Weapon System functions than previous shipboard systems. Requirements allocated to the system computers that have determined the configuration design include

1. Automated control of the multifunction array radar operations in a complex hostile environment;
2. Fully automated rapid system reaction to threats, from detection through kill;
3. High system capacities for engagement and surveillance; and
4. Continuous system availability, leading to continuous on-line readiness testing, automatic fault isolation, and rapid computer reconfiguration in the event of computer or program faults.

The operational system is designed for coordination of total combat system operations as well as the control of the basic AEGIS AAW mission areas.

Although EDM-1 is a smaller and less complex system than the operational AEGIS, many features of the configurations are common, including

1. Use of the standard AN/UYK-7 computer;
2. Use of disk memory for operational and test program and data loading;
3. Use of an electronic switch to provide multicomputer access to the disk memory;
4. Use of a central digital clock to provide a common time reference to all computers;
5. Segmentation of the computer program development into functionally identifiable separate programs; and
6. Use of a common executive program in all segments.

6.2.3 EDM-1 Computer System Configuration

For the first AEGIS engineering model, a conservative unit-computer approach was adopted. As shown previously (Fig. 6-2), four AN/UYK-7 computers are used. Two of these control the AN/SPY-1 radar, one is in the WDS, and the fourth, which has an extended memory, is used in the C,C system.

These computers use the basic one-bay AN/UYK-7 configuration, which includes one central processing unit (CPU), three 16k x 32 bit memory units (MU), one input/output controller (IOC), an input/output adapter with 16 I/O channels, and a power supply unit. The C,C computer is bus-connected to two additional MU's in an adjacent bay. All communication among CPU's is by means of MIL-STD-1397 intercomputer interface channels, under IOC control.

Figure 6-5 shows the computer configuration, major interfaces, and computer peripheral units employed.

No alternate or casualty configurations were designed for EDM-1.

6.2.4 AEGIS Baseline Computer Configuration

The AEGIS operational system computer baseline has been developed to provide projected throughput, memory, and communication capacities, with both design margin and delivery reserves, to comply with computer standardization directives and to meet system availability requirements. Major changes from the EDM-1 system are

1. Growth to 12 AN/UYK-7 processors,
2. Use of memory sharing, in a standard four-bay configuration, and
3. Use of AN/UYK-20 peripheral processors.

Projections of required computer capacity have been made based on EDM-1 design experience, approved system requirements, and examination of other AN/UYK-7 combat system programs such as the DLGN-38 computer programs.

The memory-shared configuration was developed to satisfy both performance and availability considerations. In the AN/SPY-1 control suite, where processing throughput is at a premium, inter-CPU communication via shared memory is a significantly smaller load than via I/O channels. In the C&DS, where memory space is at a premium, the central track data files can be shared by many functions. In all three suites, the shared-memory configuration enables automatic reaction to an equipment failure without mechanical switching.

6-14

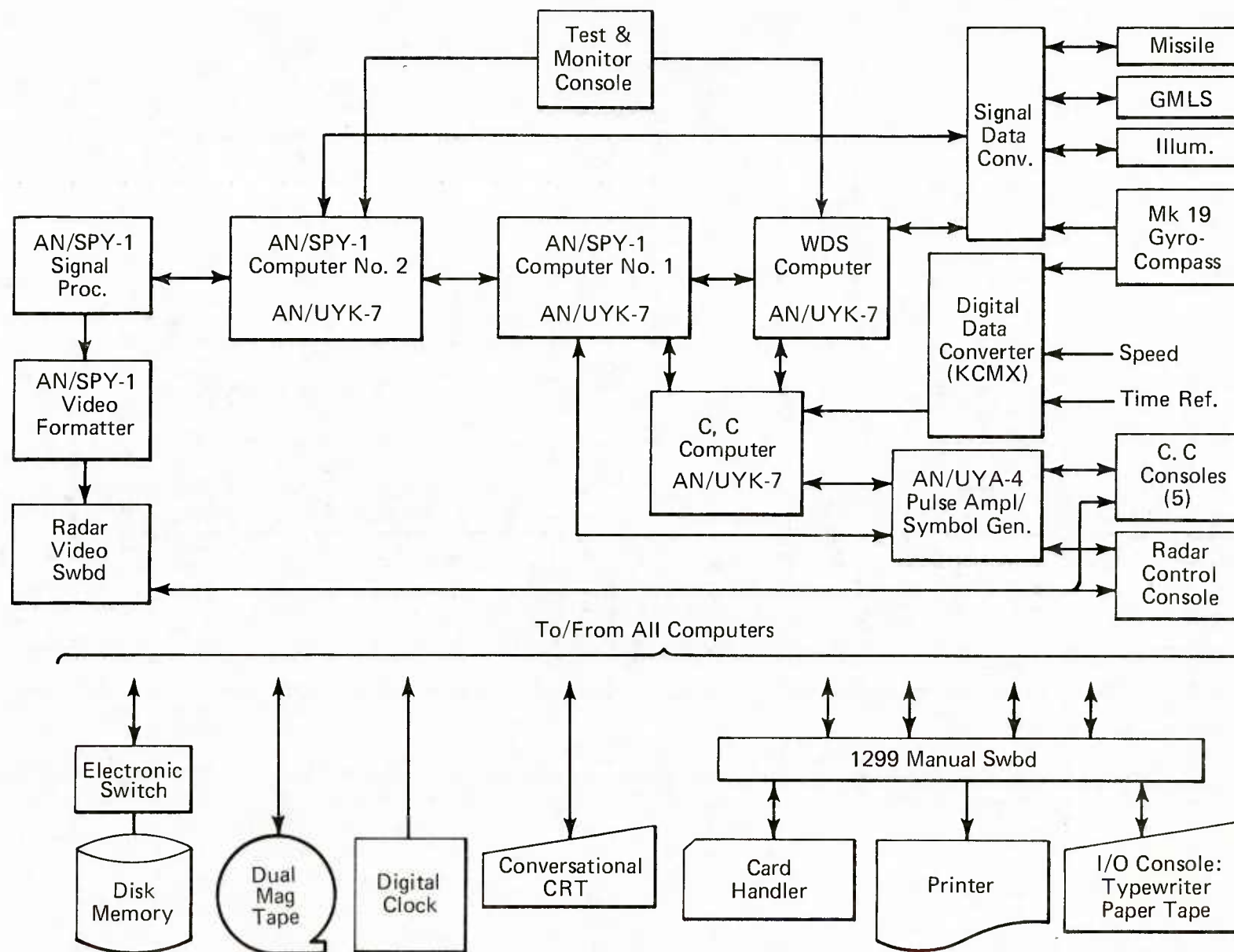


Fig. 6-5 EDM-1 Computer System Configuration

Figure 6-6 shows the CPU, IOC, and MU interconnections within a four-bay suite. In the figure, physical computer bays are indicated by shading. A double-density MU (32k x 32 bit) is indicated by a slashed MU box with two MU numbers.

AN/UYK-7 MU restrictions do not allow full interconnectivity. There is a limit of eight ports to a MU. One of these is required for IOC use, two for CPU use when the MU contains programs to be executed. Only one MU port is required for CPU data-only access. This configuration provides the full 256k unambiguous AN/UYK-7 memory space. It is a symmetrical arrangement allowing use of one three-bay alternate-mode computer program design in event of any one-bay failure. IOC connection to memory allows two IOC's access to all memory, for master and alternate load channels. CPU-IOC interconnections are restricted initially to those within a bay, since only dedicated CPU tasking is planned. If in the future a change is made to multiprocessing, provision can be made to connect two multiprocessing pairs.

The casualty approach is to treat any failure as a full-bay failure, place that bay off-line for maintenance, and load a three-bay

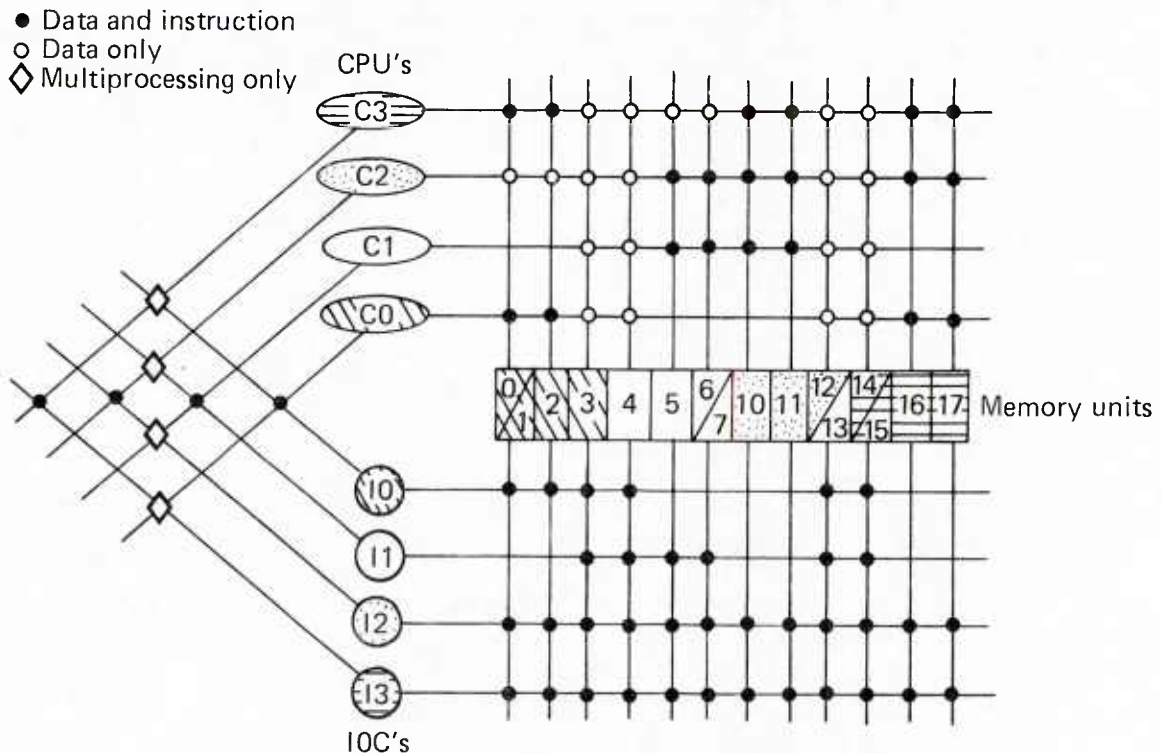


Fig. 6-6 Baseline Computer Suite Architecture

alternate program from disk. To maintain communication with external devices, two I/O channels are assigned to each critical device and an electronic switch is required at the device.

A number of benefits were found in the concept of a single configuration of the AN/UYK-7, including simplified operating system, support software, and configuration control. Since a sensible allocation of computational functions could be made in the context of three standard four-bay suites, this configuration was adopted as a baseline.

It was also found advantageous to channelize the precision control of the target illuminators by allocating this function to dedicated minicomputers. One minicomputer is allocated to each illuminator director, to provide redundancy in case of casualty. This allocation removed a potential overload in the weapon control suite and gave a configuration easily adaptable to ships with varying numbers of illuminator channels.

6.3 COMPUTER PROGRAM ARCHITECTURE

At the time of this report, the computer programs for AEGIS EDM-1 have completed design and test and have been extensively exercised in the course of AEGIS system evaluation. The computer programs for AEGIS EDM-3C are in the design phase. The following discussions will, therefore, describe the EDM-1 modular design, with indication of size and operating relationships, and give preliminary estimates of the design structure for the expanded EDM-3C system.

AEGIS EDM-1 operational computer programs include the common AEGIS Tactical Executive Program (ATEP) and programs for the four unit computers in the system.

The AEGIS EDM-3C computer programs are being designed for operational use in the first AEGIS ships. These programs consist of

1. AEGIS Tactical Executive System (ATES),
2. Programs for the three AN/UYK-7 computer suites, which are elements of the AN/SPY-1 radar, WCS, and C&DS,
3. Fire control computer programs, which execute in the channelized AN/UYK-20 computers and which will be under control of the standard AN/UYK-20 Executive Program, SDEX-20, and
4. ORTS programs, which are allocated among the three AN/UYK-7 computer suites and an AN/UYK-20.

Detailed allocation of functions to computer program modules for EDM-3C is still in the developmental stage. Where applicable, this allocation closely resembles EDM-1, especially in the radar control computers.

6.3.1 AEGIS Tactical Executive Program

6.3.1.1 EDM-1 AEGIS Tactical Executive Program

ATEP is the computer program management system that resides in and controls the processing in each of the AN/UYK-7 computers. ATEP schedules the application modules and controls the use of the computer, memory allocations, and assignment of programs and data sets, common service routines, and standard peripheral devices. ATEP performs various program services including message handling, dynamic storage allocations, error handling, standard peripheral device services, and utility services. ATEP interfaces with task state modules by a standard set of executive service requests (ESR's) for the purpose of exchanging data and command information.

The initial version of the ATEP used in EDM-1 was constrained to control of unit computers. The expanded ATEP now under development for EDM-3C is described more fully in Section 6.3.1.2.

6.3.1.2 EDM-3C AEGIS Tactical Executive System

For the EDM-3C, ATEP is divided into two component programs, the ATEP Kernel and the Application Dependent Executive Program (ADEP). This has been done to allow for installation and facility tailorability and simplification in management and development.

The ATEP Kernel provides the basic control mechanism for user modules operating in the AN/UYK-7. It operates in the interrupt state and provides centralized services that are application independent, such as the handling of interrupts, the scheduling of the overall systems operation, the apportionment of processing resources to a task, and the management of I/O. Other application-oriented executive functions such as loading, standard peripheral-device handlers, utility services, and common subroutines may be added as ADEP's.

The Kernel is designed to support each of the three major processing concepts presently used in the AN/UYK-7 computer (i.e., uniprocessing, multiprocessing, and the concept of multiple CPU's, each with its own executive communicating through shared memory).

The Kernel is tailorable. There is provision for dropping at compile time those functions not required for the particular application. For example, in a unicomputer system all multiprocessing and shared-memory features (and overhead) can be dropped. Table sizes can also be selected.

Also tailorable at compile time and at load time is the choice of the ADEP, including the choice of routines to control the standard computer peripherals (magnetic tapes, disk, and printers) and the choice of a program loader. Specific AEGIS application-oriented functions include initialization and loading, peripheral device processing, utilities, data recording, error processing, intercomputer communication, background self-test, system clock processing, and common service routines.

In order to satisfy the broad range of possible configurations, system architectures, and processing requirements, the Kernel is constructed in modular fashion. Inherent in the Kernel are the scheduling, dispatching, interrupt processing, and I/O control services. The Kernel consists of the following entities:

1. Resident Initialization Function — initializes ATEP tables and dispatches user modules at their initialization entrances.
2. Interrupt Processing Function — receives all AN/UYK-7 computer interrupts and calls the appropriate Kernel or ADEP routines.
3. Scheduling Function — enters all module scheduling requests into a priority-sequenced queue. Modules may be scheduled upon the receipt of a request from another module, or periodically after a specified interval of time, or upon the receipt of an I/O interrupt.
4. Dispatching Function — selects the request with the highest priority from the scheduling queue and dispatches this module at the specified one of seven possible entrances; it also provides module termination services.
5. I/O Processing — provides intercommunication between task-state modules and their associated IOC channel programs.
6. Memory Management Function — controls the assignment of core storage that can be dynamically assigned.
7. Message Processing Function — provides for the transmission of messages from module to module(s).
8. Fault Processing Function — makes up a data packet concerning any discovered fault and passes it on to an appropriate error processor. Manages automatic reload and reconfiguration.
9. Utility Interface Function — provides special features that enhance debugging and measurement of system performance.

The executive also supports use by a module of the following additional types of program and data-set core areas:

1. Common service routines that are accessible to modules for CPU execution.
2. Common data areas in core that may be accessed by two or more modules.
3. Temporary storage areas that are assigned upon request to a module by the Kernel.
4. Scratch pad.

A computer program that runs under the control of ATEP contains the following components:

1. Kernel
2. Selected ADEP routines
3. User-supplied program tables
4. User-defined executive tables

The computer program, containing all of the above elements is initially loaded via the Initialization and Loading function of ADEP, which then gives control to the Kernel.

The primary element in the operation of the computer is the Kernel priority scheduling queue which contains a list in priority sequence of those program modules to be dispatched (i.e., gives control of the CPU to carry out some task).

A task-state module turns over control to the Kernel via ESR's. An ESR call will cause an interrupt to the CPU, and the Kernel will then carry out the particular executive service requested by the module before returning to task state. Typical services to be carried out by the Kernel include: assigning a temporary storage data area to the module, scheduling another module as a successor, sending a message to another module, and initiating a specified I/O command to an IOC.

ATEP currently provides 100 different ESR's and 19 Common Service routines. ATEP Kernel use of computer memory ranges from 2500 to 5000 words, depending on configuration. A four-bay ATEP, including four copies of the Kernel and ADEP elements, is estimated at 35,800 words. ATEP use of computer CPU time is estimated at about 10 to 15% of each active CPU.

6.3.2 AN/SPY-1 Control Computer Program

6.3.2.1 EDM-1 AN/SPY-1 Control Computer Program

The program is divided between two computers. Figure 6-7 shows a simplified schematic of the radar control program. The squares represent modules with major data flow shown by the lines linking the modules. The primary flow of radar control orders and data is represented by the heavier lines.

Computer 1, generally referred to as the Control Computer, has as its primary functions radar scheduling, track processing, and search management. Support functions include console management for the radar control console, WDS, and C,C interfacing, and radar initialization; secondary support includes background self-test and load evaluation functions. Computer 2, generally referred to as the Face Computer, has as its primary functions output control and radar return processing. Support functions are gyro position processing and background self-test. The Face Computer's primary task is interfacing to the AN/SPY-1 Radar Signal Processor.

Table 6-2 lists the major functions performed by each of the AN/SPY-1 computer program modules and indicates their use of computer time and core. Total program core use is 42,600 32 bit words. The program uses about 119% of an AN/UYK-7 CPU. Module time statistics are scenario dependent; the values vary with the number of radar dwells scheduled and radar returns processed. Values presented in Table 6-2 are for a typical radar environment.

6.3.2.2 EDM-3C AN/SPY-1A Control Computer Program

The computer program design projected for EDM-3C is similar in structure to that of EDM-1 but expanded in scope to support four array faces and additional radar functions. The program uses four AN/UYK-7 CPU's, which communicate via shared memory.

Figure 6-8 shows the allocation of the major processing functions to CPU's and the principal flow of data. An estimated use of computer memory is 120,000 words. Processing time is strongly dependent on the scheduling of radar events and the number of targets detected. The system design has attempted to strike a balance among transmitter power, radar signal receive time, and computer processing resources. An estimate of 260% of a single CPU throughput is given for a typical heavily loaded case.

6.3.3 Weapon Control Computer Program

6.3.3.1 EDM-1 Weapon Direction Computer Program

This computer program controls the actual engagements and, therefore, interfaces with and controls the illuminators, launcher, and

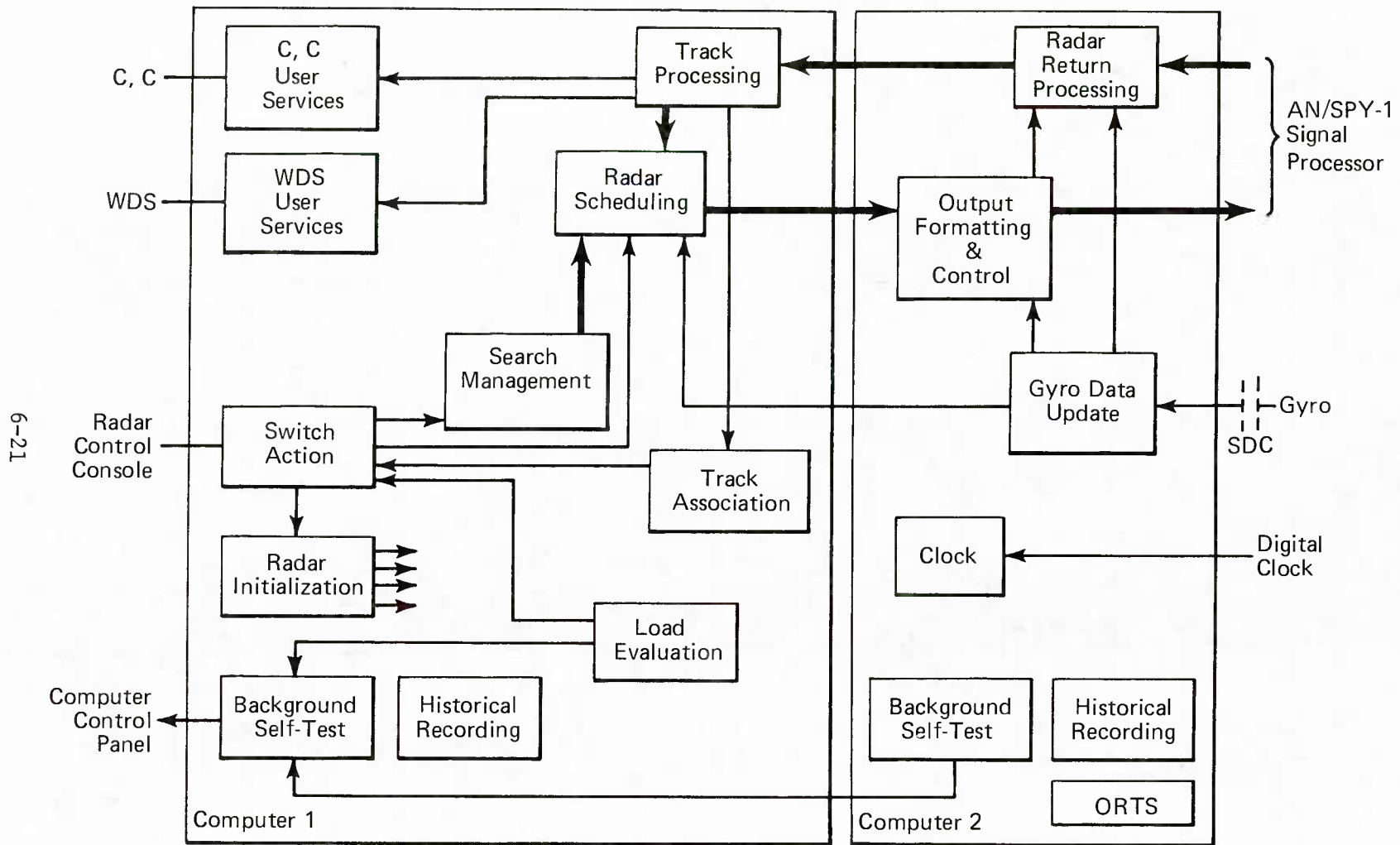


Fig. 6-7 EDM-1 AN/SPY-1 Control Computer Program Module Diagram

TABLE 6-2
AN/SPY-1 CONTROL MODULE FUNCTIONS

Module	Core	Time (% of one CPU)
Search Management Module: Generates surveillance beam requests.	3,300	1
Radar Scheduling Module: Schedules radar events such that search and track requirements are maintained.	2,000	24
Track Processing Module: Maintains track stores; correlates search detections with existing tracks. Initiates requests for tracking beams.	2,700	20
Track Association Module: Identifies track redundancies and eliminates stale tracks.	400	--
Switch Action Module: Interfaces between Radar Control Console and AN/SPY-1 Control program. Implements operator actions.	6,000	4
Load Evaluation Module: Computes radar and computer processing loads.	200	--
C,C User Services Module: Transfers and routes AN/SPY-1 Control/C,C intersegment messages.	900	--
Weapon Control User Services Module: Transfers and routes AN/SPY-1 Control/WDS intersegment messages.	900	--
Historical Recording "A" Module: Records data from AN/SPY-1 Control Computer 1.	400	--
Radar Initialization Module: Controls up and down sequence of AN/SPY-1 radar.	1,200	--
Background Self-Test "A" Module: Performs self-testing during CPU "idle time" for AN/SPY-1 Control Computer 1.	500	--
Historical Recording "B" Module: Records data from AN/SPY-1 Control Computer 2.	400	--
Output Formatting and Control Module: Computes beam stabilization parameters; interfaces between AN/SPY-1 Control and Radar Signal.	2,700	40
Radar Return Processing Module: Interfaces between Radar Signal Processor and AN/SPY-1 Control; converts coordinate systems.	2,900	28
Gyro Update Module: Smoothes and extrapolates gyro data; handles gyro to AN/SPY-1 Control interface; computes array face limits.	1,200	2
Background Self-Test "B" Module: Performs self-testing during CPU "idle time" for AN/SPY-1 Control Computer 2.	500	--
System Clock Module: Sets time of day reference.		
ATEP	8,000	--
Common Data	4,500	--
Common Services	1,800	--

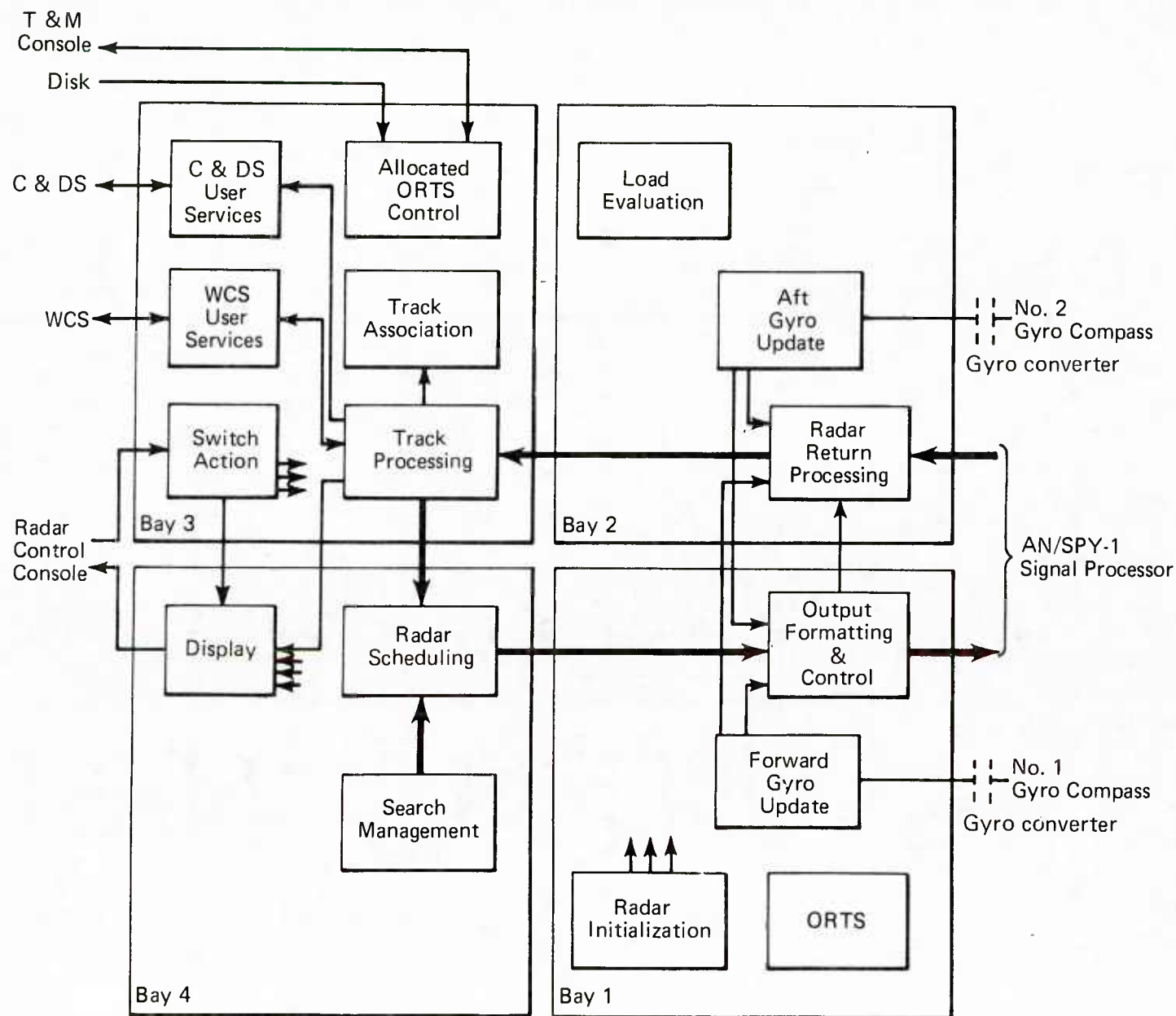


Fig. 6-8 EDM-3C AN/SPY-1 Computer Program Module Diagram

missiles through the WDS. Functions of this computer program include target engageability assessment, scheduling of engagements, control of missile loading, launcher positioning, missile preset, and the launch process, and control of illuminator scheduling and positioning for missile guidance. Figure 6-9 is a simplified block diagram of the EDM-1 WDS computer program. Table 6-3 lists the major functions performed by the WDS computer program modules and their use of computer time and core. Total program core use is 46,600 words; the program uses about 69% of an AN/UYK-7 CPU under a typical engagement load.

TABLE 6-3
EDM-1 WEAPON DIRECTION SYSTEM MODULE FUNCTIONS

Module	Core	Time (% of one CPU)
Target Scheduling Module: Processes messages from C,C segment; initiates all WDS assignments.	3,100	2.0
AN/SPY-1 Control Input Module: Processes track data messages from AN/SPY-1 Control segment; performs track smoothing.	300	0.2
Engageability Module: Computes target engageability parameters.	200	
C,C Output Module: Processes WDS to C,C messages; provides status information to C,C.	1,400	0.1
Prelaunch Module: Performs launcher parameter calculations; computes missile prelaunch parameters.	4,500	19.0
Slaved Illuminator Module: Computes SI pointing parameters; selects CWI frequency.	1,900	6.0
Ship Motion Module: Computes ship's motion matrices.	300	1.0
SDC Input Module: Processes SCD to WDS messages	300	0.2
SDC Output Module: Processes WDS to SDC messages	300	0.2
Tracking Illuminator Module: Computers TI pointing parameters; selects RF frequency pulse repetition rate.	9,000	20.0
ATEP	8,400	
Common Services	2,200	
Common Data	6,800	
I/O Buffers	1,700	
ORTS	4,900	
ORTS Overlay Area	2,300	

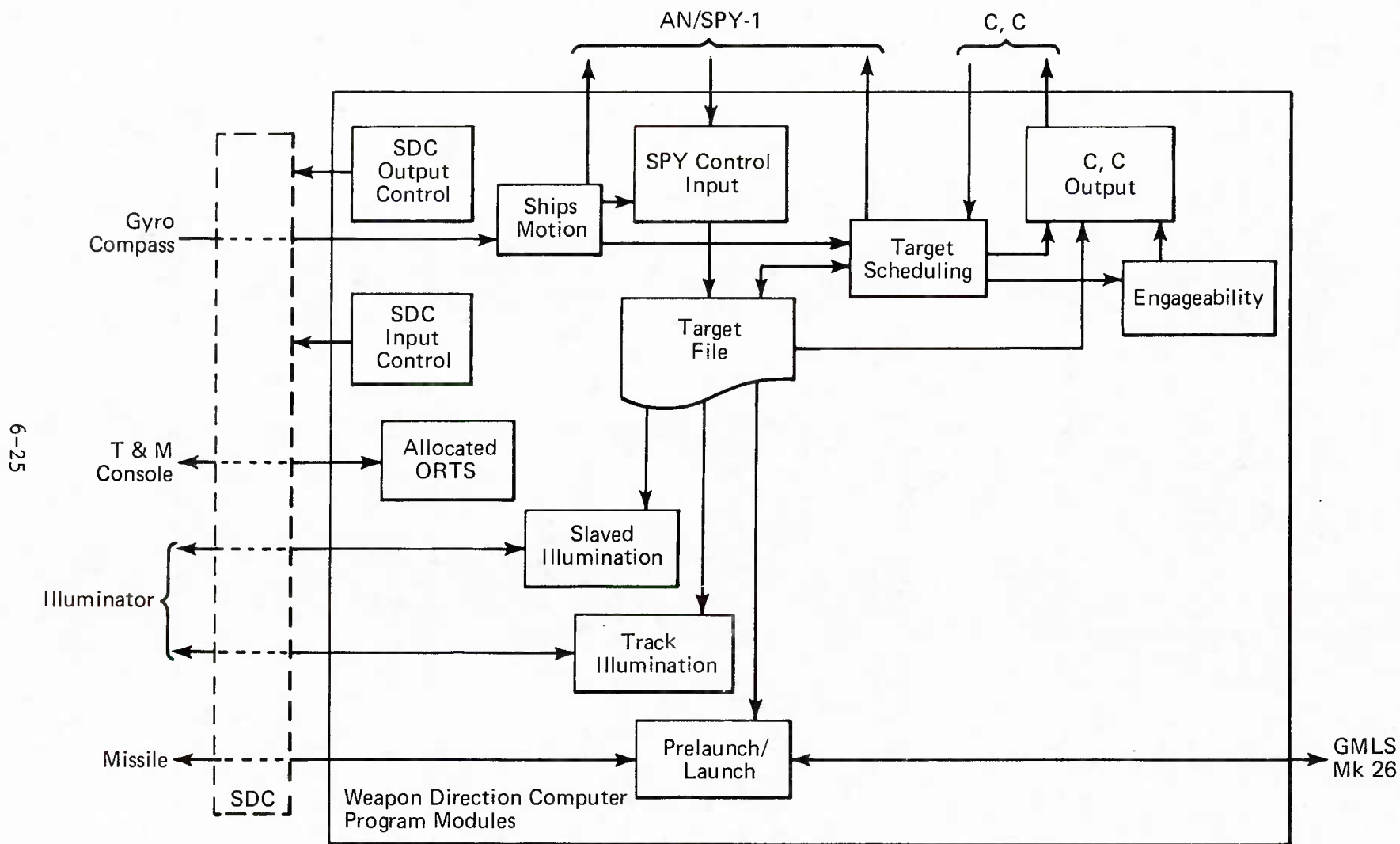


Fig. 6-9 EDM-1 WDS Computer Program Module Diagram

6.3.3.2 EDM-3C Weapons Control Computer Program

The four AN/UYK-7 computers of the EDM-3C WCS are host to control programs for SM-2 (or SM-1) missile engagement, air intercept control, LAMPS helicopter control, ASW management, and designation to other antiair and surface Weapon Systems. A portion of the FCS computer programs is hosted in this AN/UYK-7 suite. It also hosts the local control programs for ORTS.

Table 6-4 lists major functions of the WCS computer programs, with estimates of their use of memory and processing time. Total memory use is estimated at 146,100 words, including ATEs and memory assigned to local ORTS.

TABLE 6-4
EDM-3C WEAPONS CONTROL COMPUTER FUNCTIONS

Functions	Core	Time (% of one CPU)
Missile Engagement Control and Scheduling	14,600	8
AN/SPY-1 Data Processing and Smoothing	1,700	32
Engageability Computation	3,400	2
C&DS Interface/WCS Control	1,700	1
Launcher/Illuminator Management, FCS Interface	5,700*	51
Missile Guidance, Homing, and Evaluation	4,000	72
Air Control and Link 4A Management	19,500	2
LAMPS Control	10,000	5
ASW Management	8,000	1
Support of CIWS, GFCS, Harpoon, SLCM	9,600	--
Operator Support and Display	6,900	5
Support Interfaces (gyro and clock)	2,100	
ATES (4 CPU's)	35,800	(included above)
Common Services	3,800	--
Common Data	16,500	--
WCS Allocated ORTS	2,800	--

*Part of FCS.

Actual processing time is strongly dependent on the number of targets assigned and in various stages of engagement. An estimate under heavy loading is 206% of a single CPU throughput capacity.

6.3.3.3 EDM-3C Fire Control Computer Programs

The AEGIS FCS Mk 99 includes the slaved illuminators, data converters, channel selector, and one AN/UYK-20 computer for each illuminator channel. Fire control computer programs are resident in both the AN/UYK-20 computers and in one AN/UYK-7 bay of the WCS computer suite. Figure 6-10 illustrates the FCS and its computer programs.

The AN/UYK-7 computer programs are responsible for generation of a fire control solution, launcher positioning control, launch sequence control, and missile prelaunch control. The AN/UYK-20 computer programs are responsible for control over the illuminator director state and the transmitter state and position. Both the AN/UYK-7 and AN/UYK-20 computers are allocated ORTS testing functions.

The AN/UYK-7 fire control computer program is estimated to require 20,000 words of computer memory, including the ATES and allocated ORTS for that bay. An estimate for maximum CPU loading is 60%, including executive overhead.

The AN/UYK-20 computer programs are estimated to require about 23,000 words for slaved illuminator control. Maximum CPU loading in each of these computers is estimated at 26%.

The AN/UYK-20 computers will operate under control of the Navy standard SDEX-20 real-time executive program. The SDEX-20 will be augmented with a linking loader and with application-dependent processes such as fault processing, device processing, data extraction, and background self-test.

6.3.4 Command and Control Computer Programs

6.3.4.1 EDM-1 Command and Control Computer Program

The EDM-1 C,C program is limited to support of missile operations. It is used to implement and demonstrate those command and control functions essential to the operation of the AEGIS Weapon System. These are:

1. Initialization

Computer Program Initialization
C,C Readiness

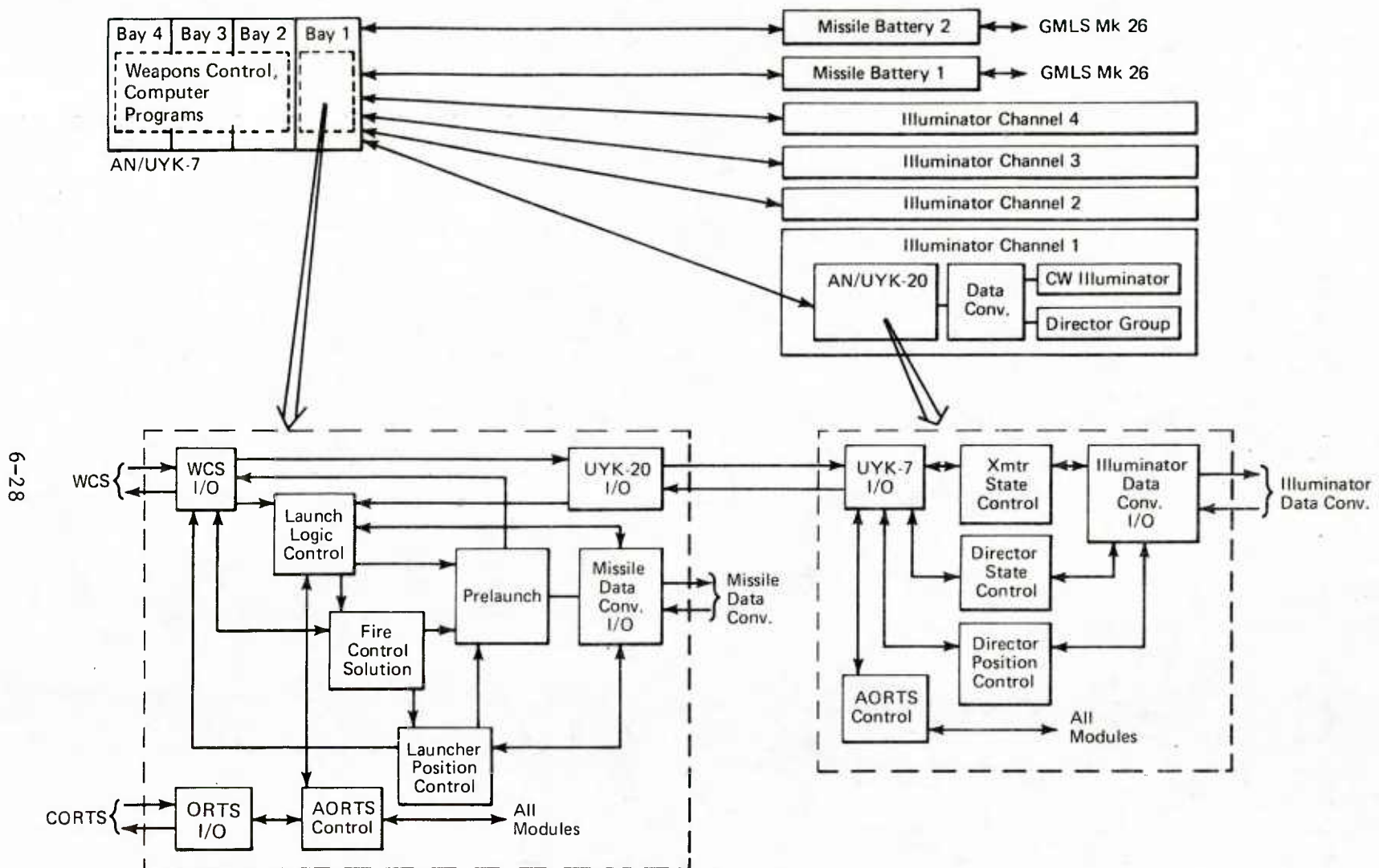


Fig. 6-10 EDM-3C Fire Control Computer Program Diagram

2. EDM System Setup
 - Special Threat Setup
 - Console Mode Setup
3. Control and Operations
 - Radar Direction
 - Weapon Direction
 - Special Points and References
 - Own Ship Position and Navigation
 - Display Console Control
4. Tracking
 - Radar Auto Tracking
 - Manual Tracking
 - Tracking Illuminator Tracking
5. Tactical Functions
 - Identification
 - Threat Evaluation
 - Weapon Assignment
 - Engagement Control
 - Time Management
6. Test Support
 - Segment Control
 - Test Direction and Recording

Figure 6-11 is a simplified schematic of the EDM-1 command and control computer program modules. Table 6-5 lists the major functions of each module and its use of computer memory. Total available core is 65,536 words. An additional 14,000 words of programs may be overlaid from disk.

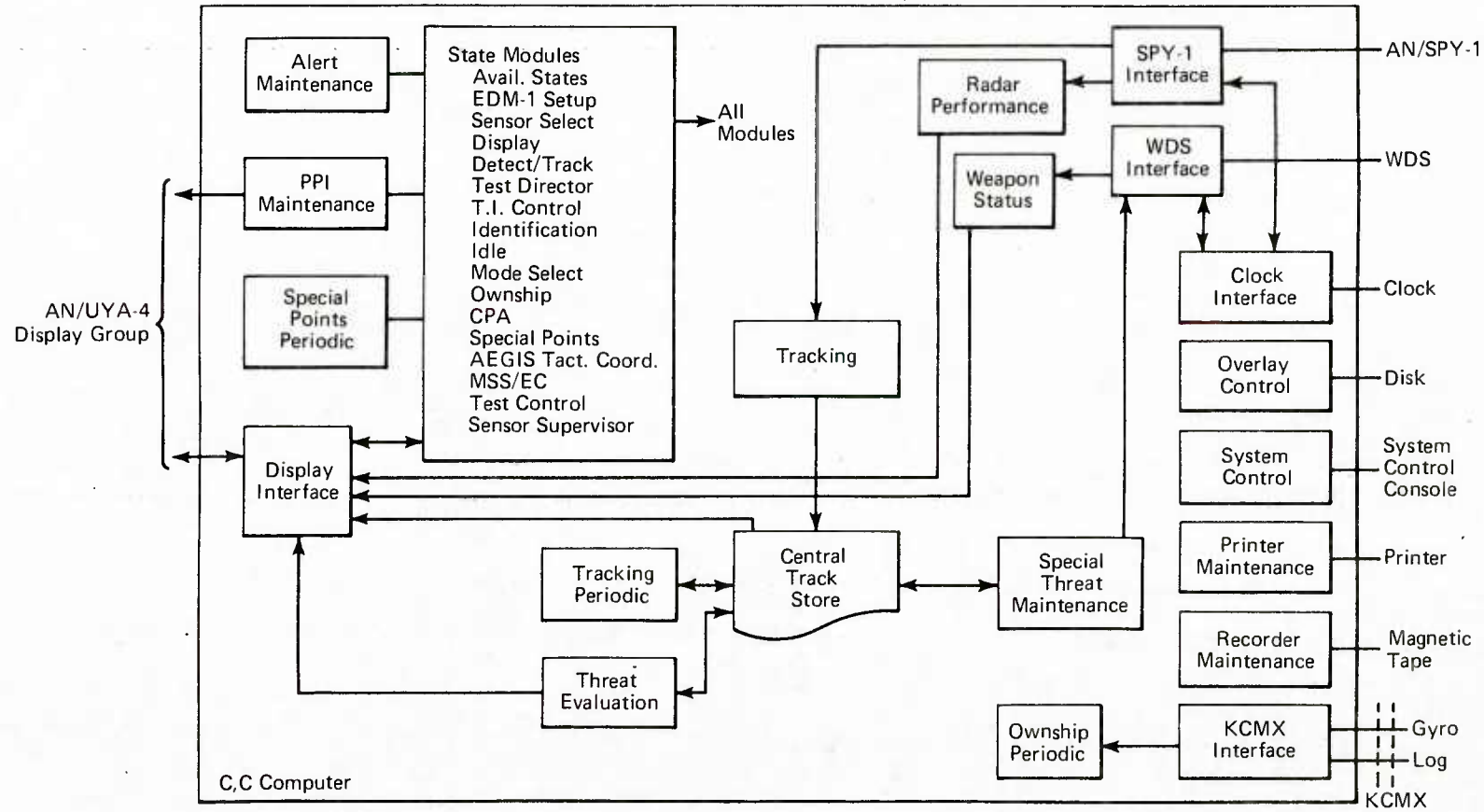


Fig. 6-11 EDM-1 Command and Control Computer Program Module Diagram

TABLE 6-5
EDM-1 COMMAND AND CONTROL MODULE FUNCTIONS

Module	Core
Printer Maintenance Module: Responds to recorder requests from other modules.	3,300
Radar Performance Module: Computes radar performance for CRT display.	1,400
Special Threat Maintenance Module: Processes and tests for special threat candidates.	1,300
Tracking Periodic Module: Reviews track performance for tracks; processes burnthrough requests to AN/SPY-1 radar.	500
Weapon Status Module: Processes weapon-oriented data from WDS.	1,600
Threat Evaluation Module: Computes and maintains threat index on tracks.	700
Console State Modules: A module is defined for each operating state of the AN/UYA-4 consoles. These modules implement the control actions taken by the system operation. EDM-1 has 17 state modules as listed:	11,200 (sum of state modules)
Available States State Module	
EDM-1 Setup State Module	
Sensor Select State Module	
Display State Module	
Detector-Tracks, Normal Operating State (NOS) Module	
Test Director NOS Module	
TI Control State	
Identification State Module	
Idle State Module	
Mode Select State Module	
Own Ship State Module	
Closest Point of Approach State Module	
Special Points State Module	
AGEIS Tactical Coordinator (ATC) NOS Module	
Missile System Supervisor/Engagement Controller (MSS/EC) NOS Module	
Test Control State Module	
Sensor Supervisor NOS Module	
Periodic Module Special Points: Updates position of fixed, moving, and slaved reference tracks.	200

TABLE 6-5
EDM-1 COMMAND AND CONTROL MODULE FUNCTIONS (continued)

Module	Core
Periodic Module Own Ship: Updates own ship heading data; maintains own ship display and PPI lines and zones as own ship data is updated.	400
Tracking Module: Maintains position and velocity information on all tracks in system.	4,100
Clock Interface Module: Checks system clock against CPU clock; responds to AN/SPY-1 and WDS clock messages.	800
Display Interface Module: Responds to messages from system control console and updates various CRT displays.	5,900
KCMX Interface Module: Interrogates Keyset Multiplexer (KCMX) for own ship data and maintains smoothed own ship parameters in data files.	600
AN/SPY-1 Interface Module: Processes intercomputer message traffic between C,C and AN/SPY-1 segments.	800
WDS Interface Module: Process intercomputer message traffic between C,C and WDS segments.	900
Alert Maintenance Module: Maintains alert queue; displays next queue at appropriate console.	800
PPI Maintenance Module: Builds PPI output buffer for consoles.	2,200
Overlay Control Module: Responds to request to bring new models in from disk.	200
System Control Module: Handles bookkeeping responsibility for intersegment messages.	2,300
Recorder Maintenance Module: Processes recording control requests from other modules.	300

6.3.4.2 EDM-3C Command and Decision Computer Programs

The EDM-3C C&DS is designed to support overall tactical direction of the entire ship's combat system. In addition to its functions directly in support of AEGIS, it must provide for the coordination of other radars and data sources, communicate with other units via the standard tactical data links, and support ASW, surface, and electronic warfare (EW) operations.

Table 6-6 gives an estimate of the computer memory requirements for major C&DS functions. Total estimated use of memory is 170,000 words. CPU utilization is estimated at about 220% of a single CPU's capacity.

TABLE 6-6
EDM-3C COMMAND AND DECISION COMPUTER FUNCTIONS

Function	Core
Sensor Control and Track Management (including central track stores)	26,000
Identification	6,000
Threat Evaluation and Weapon Selection	18,000
WCS Interface	300
Link 11	14,500
Link 14	3,000
EW Control and Data Processing	4,000
LAMPS Data Processing	8,000
Navigation	2,000
Surface Operations	9,200
Battle Short Control	1,000
Operator Support and Display	21,000
ATES (4 CPU's)	35,800
Common Buffers	6,000
System Initialization	5,000
Allocated ORTS	10,000

6.3.5 Operational Readiness Test Computer Programs

The ORTS provides continuous testing and reporting of system availability, automated fault isolation, and control of system configurations. ORTS consists primarily of the centralized Test and Monitor Console (T&MC), supplementary remote terminals, data acquisition assemblies (located throughout the AEGIS equipment), and the computer programs. Figure 6-12 illustrates the general structure of the ORTS.

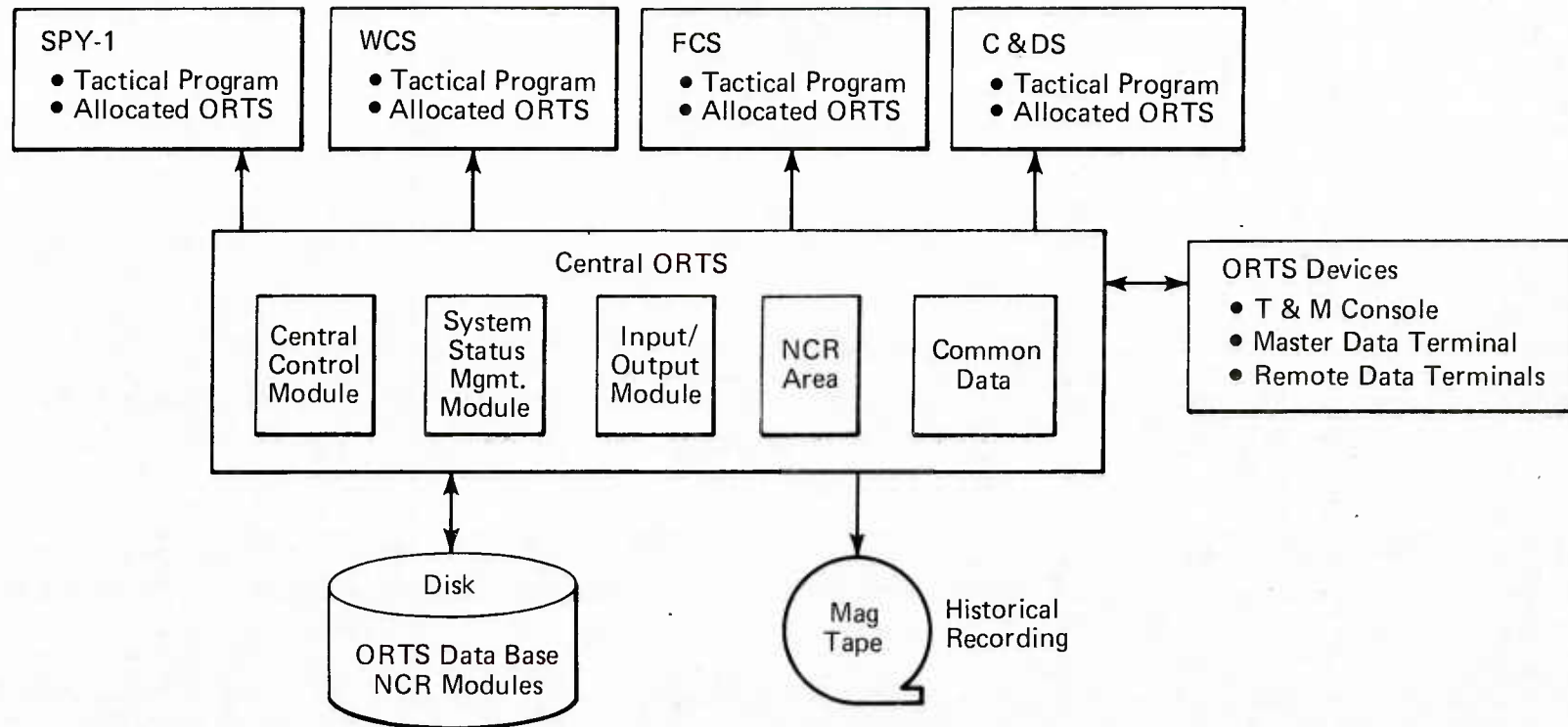


Fig. 6-12 ORTS Computer Program Diagram

The ORTS computer programs are divided into Central ORTS (CORTS), which is located in an AN/UYK-20, and Allocated ORTS (AORTS), which is distributed among all the AEGIS AN/UYK-7 and AN/UYK-20 computers. CORTS provides overall management of test operations and interfacing with the maintenance operators. AORTS controls specific tests carried out within the various segments of the system.

CORTS includes both core-resident and disk-resident elements. It is driven primarily by the disk-resident ORTS data base. The CORTS modules run in a non-interfacing background mode and thus do not figure in critical CPU timing. Table 6-7 lists the CORTS computer program modules, their primary functions, and allocation of resident computer memory. The core allocation to CORTS is 25,000 words, including resident common data and non-core-resident (NCR) buffer.

Table 6-7
CENTRAL ORTS COMPUTER PROGRAM MODULE FUNCTIONS

Module	Core
Central Control: Schedules ORTS tasks and maintenance actions, monitors test completion, controls ORTS interfaces, coordinates T&MC usage.	3,400*
System Status Management: Evaluates test results and status reports, maintains test results and system status files, reports events on historical tape, updates T&MC status panels.	2,600* +2,600 NCR
Input/Output: Controls I/O with T&MC and other operator stations, analyzes operator requests.	3,300*
Test Interpreter: Decodes, processes, and applies Test Control Language.	6,800 NCR
Test Amendment: Creates modified test files on disk.	6,300 NCR
Initialization Controller: Determines system configuration, provides operator control of initialization and reconfiguration, configuration events.	6,200 NCR
Keyboard Decoder: Decodes commands from T&MC, and other stations, validates legality, initiates response.	2,300 NCR
Reports and Displays: Prepares reports and displays from processed data and disk-resident templates.	4,000 NCR
File Management Routine	700*
Common Data	8,200*
NCR Buffer	6,800*

*Core-resident

Disk-resident ORTS may run as high as 2 million 32-bit computer words. This includes NCR program modules, test schedules, test stimuli, test results, status records, test language sequences, message display templates, initialization/recovery control sequences, and transient data.

6.4 SOFTWARE DEFINITION, DESIGN, AND IMPLEMENTATION*

The process of developing the AEGIS computer systems has been derived from that used successfully in AEGIS EDM-1.

Development of the system computer programs begins with the generation of a system specification. The system specification derives from the initial assessment studies conducted by the Navy and continues through advanced development. Basic requirements for the AEGIS system and AEGIS ships are stated by the Navy in the Development Concept Paper (DCP), Tactical Operational Requirements (TOR's), and Top Level Requirements (TLR's). The system specification translates and refines these general requirements into specific performance requirements. These in turn are allocated to specific elements (subsystems) of the combat system.

The system specification contains the top-level combat system functional design. MIL-STD-490, augmented by SECNAVINST 3560.1 for the computer program specifications, is the discipline used to document the total system design in a hierarchy of specifications. Each specification contains performance requirements allocated from a specification at the next higher level in the structure. Each specification in turn allocates requirements to a lower tier document, and each specification contains the requirements for acceptance testing at the level governed by that specification. This discipline of recording the functional design (requirements) in a hierarchy of specifications is required even where the system design is constrained by the prescribed use of existing elements.

The development process for AEGIS software is laid out in a Computer Program Development Plan. This document was written originally at the start of EDM-1 development and has been periodically revised. It provides an overview of

1. Identification of programs to be developed,
2. Method and facilities,

*The material in this section and in part of 6.5 has been adapted from an article by L. J. Schipper and R. W. Howery of RCA.

3. Schedule, and

4. Responsibilities.

Figure 6-13 depicts the total computer program development process.

6.4.1 Software Definition

A key point is that software development is embedded in system considerations. Thus, software definition begins with the system specification (Item 1 of Fig. 6-13). In accordance with MIL-STD-490, top-level system performance requirements are allocated to major subsystems known as elements. The AEGIS combat system is comprised of about 25 elements, of which C&DS, FCS, and EWS are examples. For elements already developed, the performance requirements are stated in terms of inventory item specifications, e.g., AN/UPX-29. For those in development, an element level specification is produced, e.g., FCS Mk 99 (Fig. 6-13, Item 2).

System functional definition via the specification discipline is carried out by the system prime contractor (RCA) down through the system specification level, the element level, and the program performance level. The programming subcontractor is involved starting at the element level. Lead system programmers assist in the generation of the element specifications by defining implementation constraints, e.g., available computer resources, type of computer usable, memory capacity (core), and processing ability (timing). The contractor Development Team relationships are shown in Fig. 6-14.

Each element performance specification allocates subfunctions to either equipment or computer programs. At this level of system design, hardware-software tradeoffs are a major concern. In the AEGIS program, many of these tradeoffs were completed during the EDM-1 phase. Those being performed in the current phase are mainly refinements and changes to reflect equipment design changes to take advantage of new technology, e.g., the ship attitude matrix computer for AN/SPY-1.

Functional performance requirements allocated to equipment have been developed and written into subelement performance specifications, e.g., the AN/SPY-1 transmitter or the C&D switching and conversion unit. Functional performance requirements assigned to general-purpose computer-based systems are developed and written into computer Program Performance Specifications (PPS), e.g., the FCS Mk 99 programs (Item 3, Fig. 6-13). During generation of the set of PPS's, the remaining hardware-software tradeoff activity is completed. RCA System Engineering generates the PPS for each program with assistance from the programming subcontractors in the form of more definitive implementation constraints. During PPS generation, close communication between the

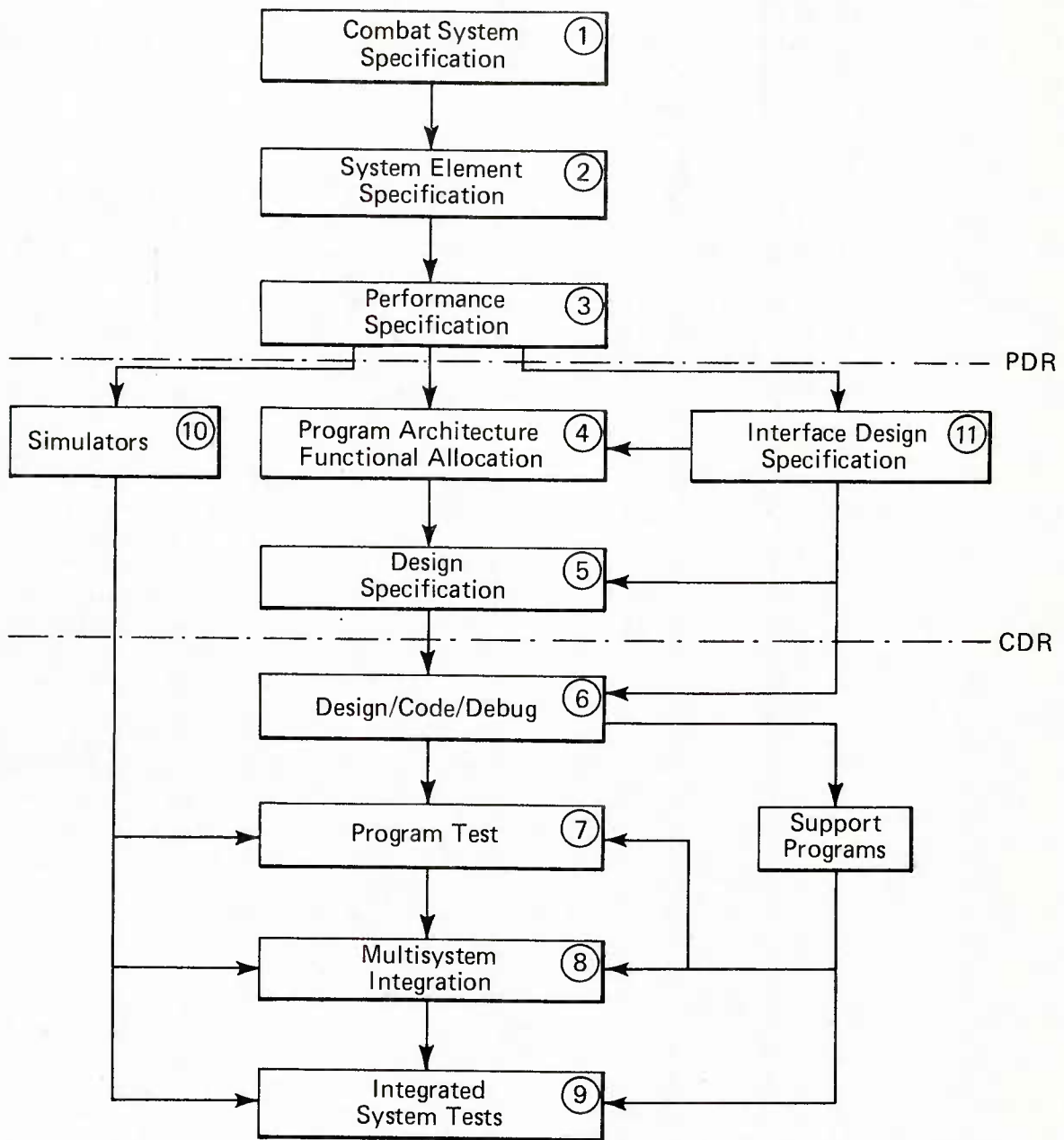


Fig. 6-13 AEGIS Combat System Computer Program Development

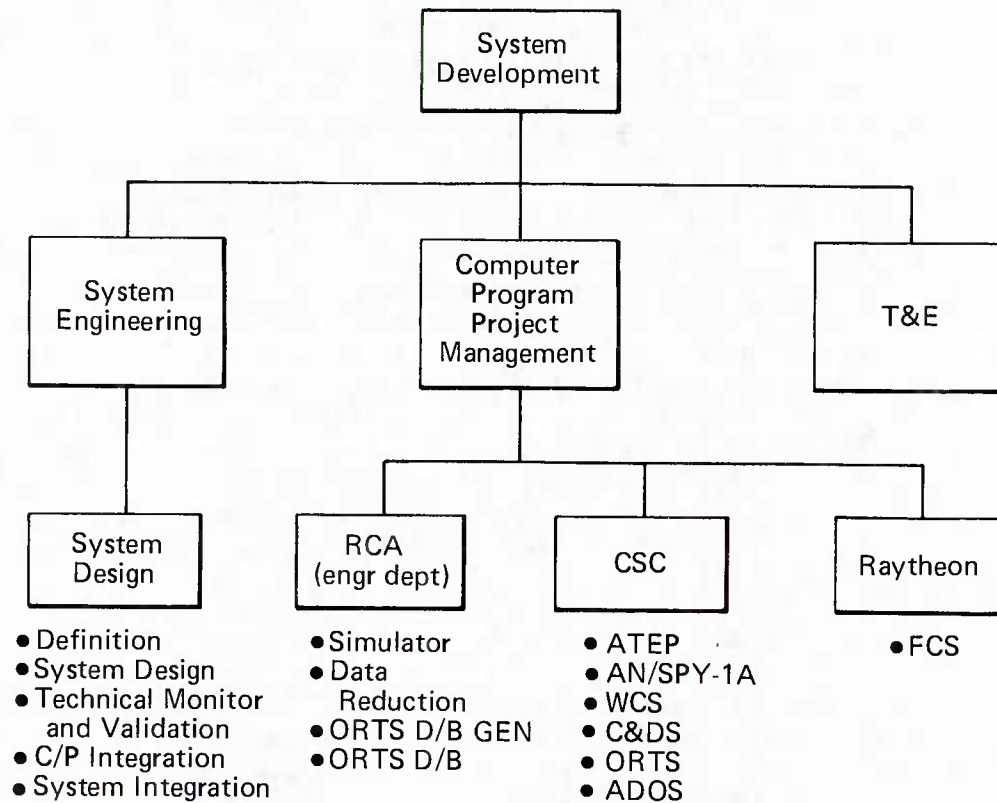


Fig. 6-14 Computer Program Development Team

system contractor and software subcontractor system programmers is maintained to assure complete and consistent specification. Methods used to ensure close liaison include the following:

1. All programmers are located at the AEGIS Programming Center facility at Computer Sciences Corporation (CSC) in proximity to RCA. The programming staff includes members from CSC, Raytheon, and the RCA Software Design Department. In addition, office facilities have been provided there for RCA System Engineering personnel to foster close liaison. The facility includes office areas and the Program Generation Center/Computer Program Test Site (CPTS).
2. Complete agreement on the PPS is assured by the System Definition Request (SDR) system. The SDR system was established during EDM-1 to enable omissions and ambiguities in the RCA-furnished PPS to be stated in writing to the RCA System Engineering staff. Responses to clarify or define are returned in writing to the problem originator. Resolution often requires a meeting of the participants either at RCA or CSC. Generation of the PPS is monitored closely by the Navy at regular In-process reviews. Approval of the specification by NAVSEA Project Management occurs in executive session at the conclusion of the Preliminary Design Review (PDR). The SDR activity continues at diminishing levels through the total project cycle as the means for requesting further system definition.

6.4.2 Software Design

Concurrent with completion of the PPS for an element, the architecture of its program is established. Functions are allocated to subprograms and relationships between subprograms are defined. The effort (Item 4, Fig. 6-13), which is a prelude to generation of a computer Program Design Specification (PDS), is performed at the Programming Center by subcontractor lead programmers with assistance from RCA project and system engineers.

Preliminary allocation of functions to subprograms is followed by iterative refinements until a definitive PDS is written. The programming subcontractor generates the PDS (Item 5, Fig. 6-13); RCA System Engineering reviews and approves the design. In-process reviews are held periodically for the Navy to assure adequate visibility of the on-going design.

Early in the design phase, interprocessor messages are defined and documented in the Interface Design Specification (IDS) in accordance

with SECNAVINST 3560.1 (Item 11, Fig. 6-13). Changes to the interfaces requested by the programming subcontractor are evaluated and approved (or disapproved) by RCA. Interfaces with existing combat system elements are defined in IDS's generated under the auspices of the Navy Combat System Manager. At the Critical Design Review (CDR), the Navy review is completed, approval is given for release of the design to coding, and the IDS's are placed under formal control.

6.4.3 Software Implementation

Coding and testing at the subprogram level and below is carried out at the Programming Center. The resultant design is documented as coded in the Program Design Document (PDD) and the Data Base Design Document (DBDD) (Item 6, Fig. 6-13).

As coding and testing progress, several partial subprograms are linked together (a "build") to evaluate the ability of the code to perform a low-level subfunction. Further into the coding and testing phase, these builds embrace additional subprograms and involve a greater portion of each to demonstrate proper execution of a major function associated with an element. Builds are established to divide the computer programs up into manageably sized tasks. These are functionally defined so that they can support an orderly growth in capability and can interface with other parts of the system (equipment or computer program). Experience on AEGIS EDM-1 shows the majority of program errors to be design related and not coding related, with the major portion found during program testing. This multiple build approach attempts to find and correct the problems early in program development.

The Computer Program Development activity is implemented at three facilities — the Program Generation Center (PGC), the CPTS, and the Combat System Engineering Development Site (CSEDS). The PGC and the CPTS are colocated at the Programming Center (at CSC). The PGC consists of the computers, peripherals, and computer program operating systems and compiler/monitor system (CMS-2Y) that support generation of computer programs from programmer coding sheets and provide documentation output for the programming design reviewers and eventually program maintenance personnel. The PGC is operated as part of the computer program library under the supervision of both Configuration Management and Quality Assurance. It is a closed shop, off limits to programming personnel as contrasted with the open shop used later at the CPTS.

Figure 6-15 shows the flow of program generation from the programmer through the definition and design developed by the system engineer and the subcontractor lead programmer, through the computer program source generation, the program compilation, and the linking of program elements that are performed in the PGC. The test of the computer program and the data reduction and analysis of the test results for evaluation by

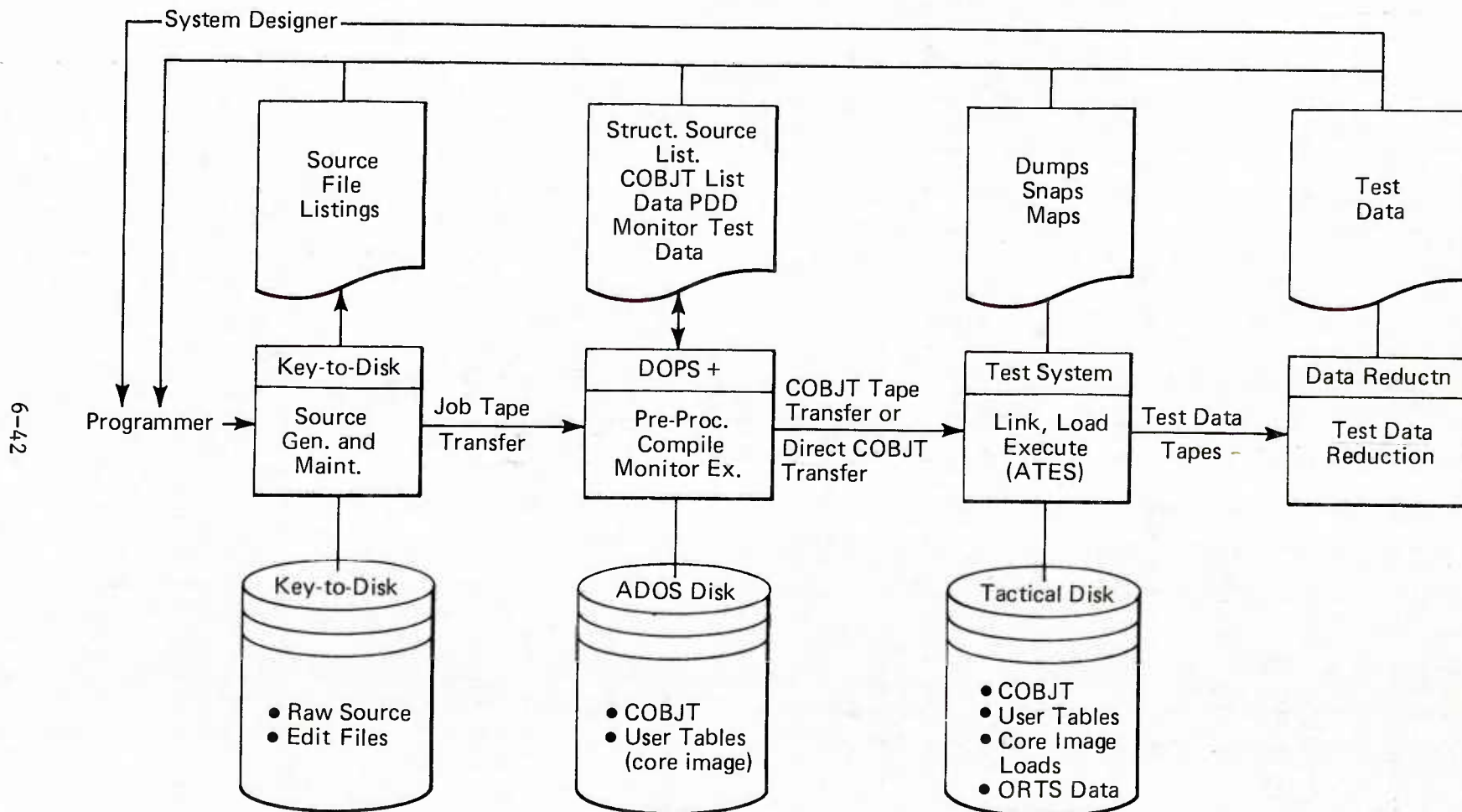


Fig. 6-15 Program Generation

the system designers and programmers are performed in the CPTS at the CSEDS. The estimated number of compilations during the peak period of computer program development is 600 per day with the PGC running on a 24 hour day, 7 day per week basis.

6.5 SOFTWARE VALIDATION AND INTEGRATION

AEGIS computer program validation and integration is closely linked to the design and implementation process and is conducted under the same management structure. The System Test Plan provides for the phased approach to testing as described in this section and prescribes formal phases of test and integration as a part of the Government Design Review and acceptance of the system. Test plans and procedures are subjected to Navy review and approval, as are the specifications which are the basis for test design.

Important aspects of the test and integration approach used by AEGIS include

1. The "build a little, test a little, integrate a little" approach, reflected in program build structure and phased test sequence,
2. Integration of computer programs with equipment early in the test sequence,
3. Development of adequate facilities for thorough land-based testing,
4. Use of authenticated simulators for interface and performance testing, and
5. Acceptance testing of individual elements, conditional on the basic requirement for overall system operational performance.

6.5.1 Software Testing

To demonstrate functional capability on a build basis, interfaces external to the element program build must be physically present or simulated with programs executing on other computers (simulators). At the Programming Center, the external interfaces are all simulated with the exception of displays and computer peripherals. The simulators (Item 10, Fig. 6-13) are analogous to test and inspection tooling in an equipment frame of reference. These are controlled by performance and design specifications and flow charts. A modular set of simulator programs is being designed and together with the associated computer

equipment configurations will be supplied to the programming subcontractors as verified replicas of the elements simulated. Program testing from the build level to the level of a complete program for a single element is carried out at the Programming Center/CPTS. Again in the test planning and procedure phase, SDR's are used to request clarification of test requirements stated in the PPS.

The CPTS is an open shop test area with an operational computer configuration and a simulator computer system to allow testing of all levels from individual element computer program builds to the final combat system multisystem computer test.

The development process is documented by Computer Program Problem Reports (CPPR's). A CPPR is generated by anyone testing or using a computer program if a problem arises in its operation. The CPPR is reviewed by a Computer Program System Review Board made up of Computer Program Project Management, System Design, and lead programmer from all computer program subcontractor disciplines. The board assigns the CPPR to an appropriate problem-solving team. This team involves the responsible program designer supported by the associated system engineer. The problem is resolved by using experimental program modification, and tested, using first patches (temporary program modification in direct code) and then recompiled test programs. At this point, a recompiled version of the program is generated with the changes separated and identified in the computer program source file. The experimental problem solving includes tests at CPTS and at CSEDS to assure solution to the problem. Formal testing at both sites of the final recompiled computer program is completed before the change identification in the source file is reviewed and the final computer program change is incorporated into the source file.

6.5.2 Software Integration

Upon completion of the initial build testing, computer program development proceeds along three parallel interrelated paths. One is the continued addition of functional capability to the individual element program, the second is the initiation of element integration between the computer program and the associated equipment, and the third is multisystem integration of sets of element computer programs. Design adjustment and modifications are driven by all three of these paths, resulting in final element computer programs that support the total combat system interrelated requirements.

As the third path of computer program development, major builds from several elements are integrated. This is the beginning of multisystem integration (Item 8, Fig. 6-13). For example, some of the joint functional capability of WCS Mk 1 and FCS Mk 99 will be evaluated using a partial program for each. Interfaces external to this two-element test will be furnished by simulators.

Multisystem integration will be used (as in EDM-1) to provide an early indication of design deficiencies and will proceed concurrently with development and test of computer programs for individual elements. Functional capabilities of combined computer systems are added in successive steps until the total set of programs has been integrated. Initial multisystem integration is carried out at the Programming Center. Later multisystem builds are taken to the Combat System Test Facility for operation with on-site combat system elements. The external interfaces for these tests include

1. The actual physical interfaces for those elements already installed and checked out (e.g., the IFF system);
2. The interfaces simulated by "hardware" for shipboard equipment not present at CSEDS; and
3. Interfaces simulated in other computers for those systems not ready for integration test.

Extending multielement integration to the test facility provides the assurance of operation with the actual interfacing systems prior to the qualification testing of element programs.

Integrated system tests are the end product of multisystem integration. In these tests, major builds for each of the elements are tested as a combined system utilizing all of the external systems required or available for a particular system demonstration. All other external interfaces are simulated by other computers. Integrated system tests are conducted to demonstrate a major facet of combat system operation, e.g., AAW demonstration. These demonstrations are increased in scope until the total combat system functional capability is achieved at Initial Operational Test and Evaluation (IOT&E).

6.6 SOFTWARE ACQUISITION MANAGEMENT ORGANIZATION AND METHODS

6.6.1 Organization

AEGIS management includes the Navy project office with its supporting elements and the prime contractor organization. Management information is summarized in Table 6-8.

Navy AEGIS project management is conducted by NAVSEA, PMS-403. Technical and management support to the project office, in specific areas, is provided by the Naval Ship Engineering Center (NAVSEC) and NAVLEX. The Naval Surface Weapons Center (NSWC) Dahlgren is the lead Navy laboratory for the system. Naval Ship Weapons Systems Engineering Station (NSWSES) has specific responsibilities for test and evaluation.

TABLE 6-8
AEGIS MANAGEMENT INFORMATION

Program Status	Engineering Development (ED) (currently in Navy evaluation of first engineering model of two-phase ED program).
Program Manager	NAVSEA, PMS-403
System Contractor	(Prime) RCA
Type Contract	Cost plus fixed fee and incentive fee
Software Contractors	CSC, Raytheon (RCA in-house)
Validation Agent	NSWSES
Maintenance Agent	FCDSSA(DN) (by letter of intent)
Software Deliverables	Operational program (3 systems) Compiler-monitor system Executive program (common) Software test and evaluation program Operational training program (5 systems) Operational readiness test program
Integration Agent	NAVSEA, PMS-403

Fleet Combat Direction System Support Activity, Dam Neck (FCDSSA(DN)) provides support with respect to eventual operational use and maintenance.

A NAVSEA Technical Representative Office is maintained at the system prime contractor's facility in addition to the normal Defense Contract Administration Services Offices (DCASO). A Naval Training Unit is also at the site.

APL/JHU has served as technical advisor to the project office since the inception of the project. Technical support has also been provided by a number of contractors, including Vitro, System Consultants Incorporated, Bird Associates, COMPTec, Auerbach, and others.

Computer system specialists have been located on the Project Manager's staff and at the Technical Representative Office, with both technical and managerial responsibilities. This has served to help

focus attention as necessary on computer system development throughout the growth of the system.

Organization of the prime contractor and subcontractors for software development was summarized in Fig. 6-14 and discussed in Section 6.4.

6.6.2 Technical Management Methods

6.6.2.1 EDM-1 Design Audit and Review

AEGIS computer program management has emphasized the definition of computer programs as deliverable configuration items and the documentation of this definition by a set of uniform specifications. The specified requirements form the basis for formal technical reviews throughout the design and development of each computer program. Concurrently, the specification test requirements are the basis for subsequent test planning documentation and testing. The technical reviews, PDR, CDR, and Configuration Audit Review (CAR) are configuration baseline management and contractual milestones.

1. Preliminary Design Review

The PDR is a formal technical review of the definition of functional performance requirements for a computer program. The PDR is accomplished either prior to or very early in the design phase to establish the system compatibility of the computer program allocation and the general design approach. The primary product of a PDR is the establishment of the documented computer program performance baseline.

The documentation establishes the functional allocation and interface relationship of the computer program to other system equipment, computer programs, and facilities to the level of detail necessary to identify the functional interfaces.

2. Critical Design Review

The CDR is a joint Navy/contractor review conducted to assure suitability of detailed design as depicted by specifications, drawings, and data that demonstrate the design approach. For a computer program, the CDR is a formal technical review of the design of the computer program. The computer program CDR will result in formal identification and approval of the specific computer programming documentation that will be released for coding and testing.

The status of outstanding action items will be considered and their impact on the totality of the CDR established. Successful completion of the specific CDR shall result in approval of the Computer Program Design Specification. The accomplishment of this milestone signifies formal approval to proceed with the coding, debugging, test, and evaluation of the computer program. The final issue of the specification is then published and placed under configuration control.

3. Configuration Audit Review

CAR is conducted for the engineering development model to verify that it is built in accordance with its specifications and drawings; that the results of tests meet specified requirements; that these requirements as allocated, individually and in total, support and meet the requirements of the AEGIS system; and that authorized changes have been properly incorporated.

The objective of CAR is to assure, at the model stage of development, that the evolving design and equipment/computer programs are responsive to the mission requirements as established in AEGIS system specifications.

6.6.2.2 Configuration Management

Configuration Management is comprised of Configuration Identification (specification documentation management, configuration-item inventory), Configuration Control (document-change control, ECP processing, SCN issuance), and Configuration Status Accounting (reporting on status of configuration items, including changes).

Configuration Management, as applied to the computer programs, is concerned with the identification of and accounting for specific configurations of computer programs. These configurations may differ either in the inclusion/exclusion of their member programs or in their form. Variation in both configuration and configuration items is reflected in the corresponding computer program documentation variations which are formally maintained. To ensure reproducibility it is essential to identify the specific media (card decks, tape reels, etc.) that contain the computer program corresponding to specific documentation. All deliverables, both configuration and data items, must be kept in correlation so that it is possible at any time to supply a specified version of a computer program together with its formal documentation.

At predefined stages, certain documents and computer programs are placed under formal configuration control. At each such stage,

generally corresponding to a formal design review, a "baseline" is established. For AEGIS, these are the Functional Baseline, Allocated Baseline, Product Configuration Baseline, and Preliminary Product Baseline, and are defined by appropriate documents. Any change that affects any of these documents or any change in the computer programs after formal configuration control has been established alters the corresponding baseline and is thus subject to formal Engineering Change Proposal (ECP) procedures in accordance with MIL-STD-480. Approved changes are formalized by Specification Change Notices (SCN's) in accordance with MIL-STD-490.

6.6.3 Computer Program Development Aids

The development of the AEGIS computer program involves a complex of many design, test, and integration activities. A means of controlling the development process throughout the life of the computer program from coding to delivery is required as well as the early design control activities and the test planning and approach. Techniques which have been used to enhance visibility and assist in development control include the following:

1. Maintenance of computer program management information in a Management Information Center (MIC),
2. Use of the Functional Flow Diagrams and Descriptions (F²D²) documentation technique for design audit and review,
3. Use of the Threads technique for computer program implementation audit and testing, and
4. Design and documentation of key tests/scenarios using a Test Information Sheet (TIS) control.

6.6.3.1 Management Information Center

The MIC is in one room located at the prime contractor and directly contributes to computer program development control by providing insight into the following areas:

1. Maximizing the visibility of current programming activity;
2. Providing direct information on principal system interfaces;
3. Providing reference data to simplify evaluation of designer schedule changes; and
4. Indicating potential problems resulting from unplanned events.

The major MIC elements are

1. Computer Program Configuration Diagrams

These block diagrams describe the general logic of all intermodule and intersystem messages and tables, as well as interfaces between modules and external equipment.

2. Configuration Status

Charts are used to report the latest estimate of storage and timing utilization for each AN/UYK-7 computer. Charts are also used to indicate the status of each source document (current, pending changes, reissues, etc.) affecting computer program control elements. These charts are updated on a continuing basis.

3. Performance Activity

Charts are maintained and updated on a weekly basis displaying current and past utilization of all AEGIS computers. Statistics are prepared indicating the effectiveness of the utilization in terms of use versus availability. AN/UYK-7 reliability as measured by mean time between failures and total time used are charted and updated on a biweekly basis.

6.6.3.2 Management Tools

Two management tools that have been used successfully to increase visibility in the audit and review process are F²D² and Threads.

F²D² was developed by RCA to depict the AEGIS system at different levels, or tiers, of functional detail. It translates the requirements of the AEGIS Weapon System into hierarchically ordered functional block diagrams and associated textual descriptions at every level of system operation. Inputs to each block and their sources are identified, as are outputs and their destinations. Required functions are indicated and, at lower levels, allocated appropriately to computer programs, equipment items, or operator stations. At every level, traceability is provided to higher and lower levels. At the lower, more detailed levels, direct reference is made to specific paragraphs within specification and/or design documents. This enables a complete system audit by making all functions traceable to approved documentation and all documentation traceable to allocated functions. This multilevel representation showing system and subsystem interrelations and interfaces thus provides the visibility to ensure that all functions have been incorporated into the design and that the design is in accordance with the system specification.

Threads, developed by CSC, is used as an audit and control tool and also assists in assuring the functional integrity of program design. A thread is the path that is traversed through system components in implementing a specific functional requirement. Requirements are defined in multiple levels of threads, e.g., system, subsystem, and process, and Threads allows these levels to be described in terms of stimulus and response. Collected groups of threads become the builds that were discussed earlier. The Threads technique also assists in conducting software/system testing since specific inserted checkpoints can be monitored along each tested pathway.

6.6.3.3 Test Information Sheets

AEGIS is using a combination of document style and organization conventions that simplifies the documentation of formal system integration test procedures. The following factors are taken into account:

1. Test requirements are known early in the development cycle, but details are not.
2. Specific tests become known during the design process, and some only after coding.
3. Specific nomenclature, including version numbers and media identification, becomes known only as testing proceeds.
4. Operating procedures and run specifications appear late in the subprogram/module development cycle.
5. Many supplementary documents, such as ATEP, I/O module specifications, and military standards, already exist and need reference only.
6. Many separate tests can be performed with the same setup (e.g., computer program and equipment configurations) or even during the same test run.

A typical TIS outline (used for AN/SPY-1 control testing) is presented in Fig. 6-16.

6.7 OPERATIONAL SOFTWARE MAINTENANCE

Since the AEGIS Weapon System is currently in the Engineering Development stage, there is no formal operational maintenance program at this time.

1.0	Introduction
1.1	Scope
1.2	Test Specification and TIS Cross-Reference
1.3	TIS Organization
1.4	Type of Test
2.0	Applicable Documents
2.1	Government Documents
2.2	Non-Government Documents
3.0	Support Requirements
3.1	Equipment Configuration
3.2	Support Computer Program Configuration
4.0	Functional Test Design
4.1	Test Run #1
4.1.1	Test Objectives
4.1.2	Test Description
4.1.2.1	Target Scenario
4.1.2.2	Test Scenario
4.1.2.2.1	Test Run Initialization
4.1.2.2.2	Event #1
4.1.2.2.3	Event #2
.	
.	
.	
4.1.2.2...n	Event #X
4.1.2.3	Post Processing Requirements
4.2	Test Run #2
4.n through 4.n.2.3 are then repeated for each test.	

Fig. 6-16 Typical Test Information Sheet (TIS) Format

6.8 HIGHLIGHTS

Design of the AEGIS system was based on extensive initial studies that established system requirements. Risk elements were largely removed through advanced development projects and competitive tradeoff analyses prior to contract award. The resulting system emphasizes modular, multifunction operation controlled by integrated UYK-7 computer bays using shared memory architecture and extensive on-line computer-controlled operational testing and fault isolation. (MP1,SE1)

Required software deliverables in the AEGIS program require, in addition to the Tactical Operational Programs, a complete set of operational on-line and off-line test programs and major support programs (Executive, Compiler/Operating System). (MP3)

PDR, CDR, and CAR were scheduled at specific document delivery points. These were supplemented by frequent in-process reviews. (AP1)

The AEGIS program required a Computer Program Development Plan as a contract deliverable. This plan included development approach, work plan, schedule, and assigned responsibilities. (AP2)

Design control and auditing techniques employed included interface design documentation, Functional Flow Diagrams & Descriptions (F²D²), and program function tracing (Threads). (SE1,IP1)

The TADSTAND requirements for delivery reserve in computer resources are being applied, as well as additional growth reserves applied to current system sizing estimates. In addition to these, blocks of computer time and memory have been reserved for future support of systems now identified as future equipment for an AEGIS ship. (SE2)

Top-down design was employed in AEGIS EDM-1 and is planned for the total combat system. Standards and directives required in the design process included MIL-STD-490 amplified by WS-8506. SECNAV Instruction 3560.1 will be included in the next phase of acquisition. Documentation has been further extended to include an AEGIS Programmer Handbook setting forth rules and constraints for nomenclature and coding. (SE3,IP2)

A structured test plan included program unit (module) testing, testing of critical functional groups (builds), segment testing with simulators, segment testing with equipment, and system integration tests. (SE3,IP3)

Major AEGIS facilities have included

1. Program Generation Centers for production and module-level program testing,

2. Factory Test Site for special-purpose equipment unit testing, including initial operation under computer control, where applicable,
3. Land-Based Test Facility for integration testing of computer programs with the total system, and
4. Shipboard Evaluation Facility for evaluation of system operation in actual operating environment. (IP1,IP3)

Throughout the Engineering Development phase the Program Manager Office (PMO) has exercised strong control to ensure contractor compliance with contract provisions relating to software design and integration and test requirements with the hardware assemblies. The Government team for system review and contract monitoring has included computer system specialists in the program office, the NAVSEA Technical Representative Office (at the contractor's site), the technical advisor (APL/JHU), the maintenance agency (FCDSSA(DN)), and other contracted advisors. (MS1,MS2)

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